REPORT

OF THE

FOURTEENTH MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE;

HELD AT YORK IN SEPTEMBER 1844.

LONDON:

JOHN MURRAY, ALBEMARLE STREET.

1845.

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OF

THE ASSOCIATION.

OBJECTS.

THE ASSOCIATION contemplates no interference with the ground occupied by other Institutions. Its objects are,—To give a stronger impulse and a more systematic direction to scientific inquiry,—to promote the intercourse of those who cultivate Science in different parts of the British Empire, with one another, and with foreign philosophers,—to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind which impede its progress.

RULES.

MEMBERS.

All persons who have attended the first Meeting shall be entitled to become Members of the Association, upon subscribing an obligation to conform to its Rules.

The Fellows and Members of Chartered Literary and Philosophical Societies publishing Transactions, in the British Empire, shall be entitled, in like manner, to become Members of the Association.

The officers and Members of the Councils, or Managing Committees, of Philosophical Institutions, shall be entitled, in like manner, to become Members of the Association.

All Members of a Philosophical Institution, recommended by its Council or Managing Committee, shall be entitled, in like manner, to become Members of the Association.

Persons not belonging to such Institutions shall be elected by the General Committee or Council, to become Members of the Association, subject to the approval of a General Meeting.

SUBSCRIPTIONS.

The amount of the Annual Subscription shall be One Pound, to be paid in advance upon admission; and the amount of the composition in lieu thereof, Five Pounds.

An admission fee of One Pound is required from all Members elected as Annual Subscribers, after the Meeting of 1839, in addition to their annual subscription of One Pound.

The volume of Reports of the Association will be distributed gratuitously to every Annual Subscriber who has actually paid the Annual Subscription for the year to which the volume relates, and to all those Life Members who shall have paid Two Pounds as a *Book Subscription.*

Subscriptions shall be received by the Treasurer or Secretaries.

If the Annual Subscription of any Member shall have been in arrear for two years, and shall not be paid on proper notice, he shall cease to be a Member.

MEETINGS.

The Association shall meet annually, for one week, or longer. The place of each Meeting shall be appointed by the General Committee at the previous Meeting; and the Arrangements for it shall be entrusted to the Officers of the Association.

GENERAL COMMITTEE.

The General Committee shall sit during the week of the Meeting, or longer, to transact the business of the Association. It shall consist of the following persons:—

1. Presidents and Officers for the present and preceding years, with authors of Reports in the Transactions of the Association.
2. Members who have communicated any Paper to a Philosophical Society, which has been printed in its Transactions, and which relates to such subjects as are taken into consideration at the Sectional Meetings of the Association.
3. Office-bearers for the time being, or Delegates, altogether not exceeding three in number, from any Philosophical Society publishing Transactions.
4. Office-bearers for the time being, or Delegates, not exceeding three, from Philosophical Institutions established in the place of Meeting, or in any place where the Association has formerly met.
5. Foreigners and other individuals whose assistance is desired, and who are specially nominated in writing for the Meeting of the year by the President and General Secretaries.
6. The Presidents, Vice-Presidents, and Secretaries of the Sections are *ex officio* members of the General Committee for the time being.

SECTIONAL COMMITTEES.

The General Committee shall appoint, at each Meeting, Committees, consisting severally of the Members most conversant with the several branches of Science, to advise together for the advancement thereof.

The Committee shall report what subjects of investigation they would particularly recommend to be prosecuted during the ensuing year, and brought under consideration at the next Meeting.

The Committees shall recommend Reports on the state and progress of particular Sciences, to be drawn up from time to time by competent persons, for the information of the Annual Meetings.

COMMITTEE OF RECOMMENDATIONS.

The General Committee shall appoint at each Meeting a Committee, which shall receive and consider the recommendations of the Sectional Committees, and report to the General Committee the measures which they would advise to be adopted for the advancement of Science.

All Recommendations of Grants of Money, Requests for Special Researches, and Reports on Scientific Subjects, shall be submitted to the Committee of Recommendations, and not taken into consideration by the General Committee unless previously recommended by the Committee of Recommendations.

LOCAL COMMITTEES.

Local Committees shall be formed by the Officers of the Association to assist in making arrangements for the Meetings.

Local Committees shall have the power of adding to their numbers those Members of the Association whose assistance they may desire.

OFFICERS.

A President, two or more Vice-Presidents, one or more Secretaries, and a Treasurer, shall be annually appointed by the General Committee.

COUNCIL.

In the intervals of the Meetings, the affairs of the Association shall be managed by a Council appointed by the General Committee. The Council may also assemble for the despatch of business during the week of the Meeting.

PAPERS AND COMMUNICATIONS.

The Author of any paper or communication shall be at liberty to reserve his right of property therein.

ACCOUNTS.

The Accounts of the Association shall be audited annually, by Auditors appointed by the Meeting.

OFFICERS AND COUNCIL, 1844—45.

Trustees (*permanent*).—Roderick Impey Murchison, Esq., F.R.S., P. Geog. S. John Taylor, Esq., F.R.S. The Very Reverend G. Peacock, D.D., Dean of Ely, F.R.S.

President.—The Very Reverend George Peacock, D.D., Dean of Ely.

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Vice-Presidents Elect.—The Right Hon. The Earl of Hardwicke. The Right Reverend the Lord Bishop of Norwich. The Rev. John Graham, D.D., Master of Christ's College. Rev. Gilbert Ainslie, D.D., Master of Pembroke Hall. G. B. Airy, Esq., F.R.S., Astronomer Royal. Rev. Adam Sedgwick, F.R.S., Woodwardian Professor.

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Auditors.—Robert Hutton, Esq. Leonard Horner, Esq. Lieut.-Col. Sykes.

I. Table showing the Places and Times of Meeting of the British Association, with Presidents, Vice-Presidents, and Local Secretaries, from its Commencement.

Presidents.	Vice-Presidents.	Local Secretaries.
The EARL FITZWILLIAM, D.C.L., F.R.S., F.G.S., &c. YORK, September 27, 1831.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	William Gray, jun., F.G.S. Professor Phillips, F.R.S., F.G.S.
The REV. W. BUCKLAND, D.D., F.R.S., F.G.S., &c. OXFORD, June 19, 1832.	Sir David Brewster, F.R.SS.L. & E., &c. Rev. W. Whewell, F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c. Rev. Professor Powell, M.A., F.R.S., &c.
The REV. ADAM SEDGWICK, M.A., V.P.R.S., V.P.G.S. CAMBRIDGE, June 25, 1833.	G. B. Airy, F.R.S., Astronomer Royal, &c. John Dalton, D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.
Sir T. MACDOUGAL BRISBANE, K.C.B., D.C.L., F.R.SS. L. & E. EDINBURGH, September 8, 1834.	Sir David Brewster, F.R.S., &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.S., L. & E., &c. Sir John Robison, Sec. R.S.E.
The REV. PROVOST LLOYD, LL.D. DUBLIN, August 10, 1835.	Viscount Oxmantown, F.R.S., F.R.A.S. Rev. W. Whewell, F.R.S., &c.	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.
The MARQUIS OF LANSDOWNE, D.C.L., F.R.S., &c. BRISTOL, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S., F.G.S. J. C. Prichard, M.D., F.R.S.	Professor Daubeny, M.D., F.R.S., &c. V. F. Hovenden.
The EARL OF BURLINGTON, F.R.S., F.G.S., Chan. Univ. London. LIVERPOOL, September 11, 1837.	The Bishop of Norwich, P.L.S., F.G.S. John Dalton, D.C.L., F.R.S. Sir Philip Grey Egerton, Bart., F.R.S., F.G.S. Rev. W. Whewell, F.R.S.	Professor Traill, M.D. Wm. Wallace Currie, Esq. Joseph N. Walker, Pres. Royal Institution, Liverpool.
The DUKE OF NORTHUMBERLAND, F.R.S., F.G.S., &c. NEWCASTLE-ON-TYNE, August 20, 1838.	The Bishop of Durham, F.R.S., F.S.A. The Rev. W. Vernon Harcourt, F.R.S., &c. Prideaux John Selby, Esq., F.R.S.E.	John Adamson, F.L.S., &c. Wm. Hutton, F.G.S. Professor Johnston, M.A., F.R.S.
The REV. W. VERNON HARCOURT, M.A., F.R.S., &c. BIRMINGHAM, August 26, 1839.	The Marquis of Northampton The Earl of Dartmouth The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S. Very Rev. Principal Macfarlane	George Barker, Esq., F.R.S. Peyton Blakiston, M.D. Joseph Hodgson, Esq., F.R.S. Follett Osler, Esq.
The MOST NOBLE THE MARQUIS OF BREADALBANE. GLASGOW, September 17, 1840.	Major-General Lord Greenock, F.R.S.E. Sir David Brewster, F.R.S. Sir T. M. Brisbane, Bart., F.R.S.	Andrew Liddell, Esq. Rev. J. P. Nicol, LL.D. John Strang, Esq.
The REV. PROFESSOR WHEWELL, F.R.S., &c. PLYMOUTH, July 29, 1841.	The Earl of Mount Edgecumbe The Earl of Morley Lord Eliot, M.P. Sir C. Lemon, Bart. Sir T. D. Acland, Bart.	Wm. Snow Harris, Esq., F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, F.R.S. Richard Taylor, jun., Esq.
LORD FRANCIS EGERTON, F.G.S. MANCHESTER, June 23, 1842.	John Dalton, D.C.L., F.R.S. Hon. and Rev. W. Herbert, F.L.S., &c. Rev. A. Sedgwick, M.A., F.R.S. W. C. Henry, M.D., F.R.S. Sir Benjamin Heywood, Bart.	Peter Clare, Esq., F.R.A.S. W. Fleming, M.D. James Heywood, Esq., F.R.S.
The EARL OF ROSSE. CORK, August 17, 1843.	Earl of Listowel Viscount Adare Sir W. R. Hamilton, Pres. R.I.A. Rev. T. R. Robinson, D.D.	Professor John Stevelly, M.A. Rev. Jos. Carson, F.T.C. Dublin. Wm. Keleher, Esq. Wm. Clear, Esq.
The REV. G. PEACOCK, D.D., (Dean of Ely), F.R.S. YORK, September 26, 1844.	The Earl Fitzwilliam, F.R.S Viscount Morpeth, F.G.S. The Hon. John Stuart Wortley, M.P. Sir David Brewster, K.H. Michael Faraday, Esq., F.R.S. Rev. W. V. Harcourt, F.R.S.	William Hatfeild, Esq., F.G.S. Thomas Meynell, Esq., F.L.S. Rev. W. Scoresby, LL.D., F.R.S. William West, Esq.
SIR JOHN F. W. HERSCHEL, Bart., F.R.S., &c. CAMBRIDGE, June 19, 1845.	The Earl of Hardwicke The Bishop of Norwich The Rev. J. Graham, D.D. The Rev. G. Ainslie, D.D. G. B. Airy, Esq., F.R.S. The Rev. Professor Sedgwick, M.A., F.R.S.	William Hopkins, Esq., F.R.S. Professor Ansted, F.G.S.

II. Table showing the Members of Council of the British Association from its commencement, in addition to Presidents, Vice-Presidents, and Local Secretaries, for a list of whom see p. viii.

General Secretaries.	Rev. Wm. Vernon Harcourt, F.R.S., &c.	1832—1836.
	Francis Baily, V.P. and Treas. R.S.	1835.
	R. I. Murchison, F.R.S., F.G.S.	1836—1844.
	Rev. G. Peacock, F.R.S., F.G.S., &c.	1837, 1838.
	Lieut.-Colonel Sabine, V.P.R.S.	1839, 1844.
General Treasurer.	John Taylor, F.R.S., Treas. G.S., &c.	1832—1844
Trustees (permanent.)	Charles Babbage, F.R.SS. L. & E., &c. (Resigned.)	
	R. I. Murchison, F.R.S., &c.	
	John Taylor, F.R.S., &c.	
	Francis Baily, F.R.S., (Deceased.)	
	The Dean of Ely.	
Assistant General Secretary.	Professor Phillips, F.R.S., &c.	1832—1844.

Members of Council.

G. B. Airy, F.R.S., Astronomer Royal	1834, 1835, 1841.
Neil Arnott, M.D.	1838, 1839, 1840.
Francis Baily, V.P. and Treas. R.S.	1837—1839.
Sir H. T. De la Beche, F.R.S.	1841—1844.
George Bentham, F.L.S.	1834, 1835.
Robert Brown, D.C.L., F.R.S.	1832, 1834, 1835, 1838—1841.
Sir David Brewster, F.R.S., &c.	1832, 1841—1842.
Sir Thomas Brisbane, Bart.	1842.
Sir M. I. Brunel, F.R.S., &c.	1832.
Rev. Professor Buckland, D.D., F.R.S., &c.	1833, 1835, 1838—1844.
The Earl of Burlington, F.R.S.	1838, 1839.
Rev. T. Chalmers, D.D., Prof. of Divinity, Edinburgh	1833.
Professor Clark, Cambridge	1838.
Professor Christie, F.R.S., &c.	1833—1837.
William Clift, F.R.S., F.G.S.	1832—1835.
J. C. Colquhoun, Esq.	1840.
John Corrie, F.R.S., &c.	1832.
Professor Daniell, F.R.S.	1836, 1839.
Dr. Daubeny, F.R.S.	1838—1844.
J. E. Drinkwater	1834, 1835.
Sir Philip G. Egerton, Bart., F.R.S.	1840, 1841.
The Earl Fitzwilliam, D.C.L., F.R.S., &c.	1833.
Professor Forbes, F.R.S. L. & E., &c.	1832, 1841, 1842.
Davies Gilbert, D.C.L., V.P.R.S., &c.	1832.
Professor R. Graham, M.D., F.R.S.E.	1837.
Professor Thomas Graham, F.R.S.	1838, 1839—1844.
John Edward Gray, F.R.S., F.L.S., &c.	1837—1839, 1840, 1843.
Professor Green, F.R.S., F.G.S.	1832.
G. B. Greenough, F.R.S., F.G.S.	1832—1839—1843.
Henry Hallam, F.R.S., F.S.A., &c.	1836.
Rev. W. V. Harcourt, F.R.S.	1842.
Sir William R. Hamilton, Astron. Royal of Ireland, M.R.I.A.	1832, 1833, 1836.
W. J. Hamilton, Sec. G.S.	1840—1842.
W. Snow Harris, F.R.S.	1844.
James Heywood, Esq., F.R.S.	1843, 1844.
Rev. Prof. Henslow, M.A., F.L.S., F.G.S.	1837.
Sir John F. W. Herschel, Bart., F.R.S. L. & E., F.R.A.S., F.G.S., &c.	1832.
Thomas Hodgkin, M.D.	1833—1837, 1839, 1840, 1842.
Eaton Hodgkinson, Esq., F.R.S.	1843, 1844.
Prof. Sir W. J. Hooker, LL.D., F.R.S., &c.	1832.
Leonard Horner, F.R.S.	1841—1844.

Rev. F. W. Hope, M.A., F.L.S.	1837.
Robert Hutton, F.G.S., &c.	1836, 1838, 1839—1843, 1844.
Professor R. Jameson, F.R.S. L. & E.	1833.
Rev. Leonard Jenyns, F.L.S.	1838.
H. B. Jerrard, Esq.	1840.
Dr. R. Lee	1839.
Sir Charles Lemon, Bart., F.R.S.	1838, 1839, 1842—1844.
Rev. Dr. Lardner	1838, 1839.
Professor Lindley, F.R.S., F.L.S., &c.	1833, 1836.
Rev. Prof. Lloyd, D.D., F.R.S., M.R.I.A.	1832, 1833, 1841—1843.
J. W. Lubbock, F.R.S., F.L.S., &c., Vice-Chancellor of the University of London	1833—1836, 1838, 1839.
Rev. Thomas Luby	1832.
Charles Lyell, jun., F.R.S.	1838, 1839, 1840, 1843, 1844.
Professor MacCullagh, M.R.I.A.	1843, 1844.
William Sharp MacLeay, F.L.S.	1837.
Professor John Macneill	1843.
Professor Miller, F.G.S.	1840.
Professor Moseley, F.R.S.	1839, 1840, 1843.
Patrick Neill, LL.D., F.R.S.E.	1833.
The Marquis of Northampton, P.R.S.	1840—1843, 1844.
Professor Richard Owen, F.R.S., F.L.S.	1836, 1838, 1839, 1844.
Rev. George Peacock, M.A., F.R.S., &c.	1832, 1834, 1835, 1839—1842.
E. Pendarves, Esq., F.R.S.	1840.
Rev. Professor Powell, M.A., F.R.S., &c.	1836, 1837, 1839, 1840.
J. C. Prichard, M.D., F.R.S., &c.	1832.
George Rennie, F.R.S.	1833—1835, 1839, 1841.
Sir John Rennie, F.R.S.	1838.
Dr. Richardson, F.R.S.	1841—1843.
Rev. Professor Ritchie, F.R.S.	1833.
Rev. T. R. Robinson, D.D.	1841, 1844.
Sir John Robison, Sec. R.S.E.	1832, 1836, 1841, 1842.
P. M. Roget, M.D., Sec. R.S., F.G.S., &c.	1834—1837, 1841, 1842.
The Earl of Rosse, F.R.S.	1844.
Capt. Sir J. C. Ross, R.N., F.R.S.	1844.
Lieut.-Colonel Sabine, F.R.S.	1838.
Lord Sandon	1840.
Rev. Professor Sedgwick, M.A., F.R.S.	1842, 1843.
Rev. William Scoresby, B.D., F.R.S. L. & E.	1842.
H. E. Strickland, Esq., F.G.S.	1840—1842, 1844.
Lieut.-Col. W. H. Sykes, F.R.S., F.L.S., &c.	1837—1839, 1842—1844.
H. Fox Talbot, Esq., F.R.S.	1840.
Rev. J. J. Tayler, B.A., Manchester	1832.
William Thompson, F.L.S.	1843, 1844.
Professor Traill, M.D.	1832, 1833.
N. A. Vigors, M.P., D.C.L., F.S.A., F.L.S.	1832, 1836, 1840.
James Walker, Esq., P.S.C.E.	1840.
Captain Washington, R.N.	1838, 1839, 1840.
Professor Wheatstone, F.R.S.	1838—1844.
H. Warburton, Esq., F.R.S., Pres. G.S.	1844.
Rev. W. Whewell, F.R.S., Master of T.C. Camb.	1838, 1839, 1842, 1843.
Professor C. J. B. Williams, M.D., F.R.S.	1842—1844.
Rev. Prof. Willis, M.A., F.R.S.	1842.
William Yarrell, F.L.S.	1833—1836.
James Yates, Esq., M.A., F.R.S.	1842.

Secretaries to the Council.	Edward Turner, M.D., F.R.SS. L. & E.	1832—1836.
	James Yates, F.R.S., F.L.S., F.G.S.	1831—1840.

OFFICERS OF SECTIONAL COMMITTEES AT THE YORK MEETING.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President.—The Earl of Rosse, F.R.S.

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Secretaries.—Professor Stevelly, M.A. Rev. Wm. Hey, M.A., F.G.S.

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(including their applications to Agriculture and the Arts.).

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Vice-Presidents.—Marquis of Northampton, F.R.S. Professor Grove, F.R.S. Dr. Daubeny, F.R.S.

Secretaries.—Dr. L. Playfair. E. Solly, Esq., F.R.S. T. H. Barker, Esq.

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Vice-Presidents.—Sir John V. B. Johnstone, Bart., F.G.S. Sir C. Lemon, Bart. T. Tooke, Esq. G. R. Porter, Esq.

Secretaries.—James Heywood, Esq. Joseph Fletcher, Esq. Dr. Laycock.

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Vice-Presidents.—J. Scott Russell, F.R.S.E. Eaton Hodgkinson, F.R.S.

Secretaries.—C. Vignoles, Esq. Thomas Webster, Esq.

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BRITISH ASSOCIATION FOR THE

TREASURER'S ACCOUNT from

RECEIPTS.

	£	s.	d.	£	s.	d.
To Balance in hand from last year's Account				496	5	1
To Life Compositions received at the Cork Meeting and since	160	0	0			
To Annual Subscriptions ......Ditto......Ditto......Ditto......	446	0	0			
				606	0	0
To received for Ladies' Tickets at the Cork Meeting				160	0	0
To received for Sections' ....Ditto.........Ditto............				33	0	0
To received Compositions for Books (future publication) ...				66	0	0
To received Dividends of £5500 in the 3 per cent. Consols, 12 months to July 1844				165	0	0
To received from the Sale of Reports, viz.						
1st vol., 2nd Edition	2	12	4			
2nd vol.	3	0	0			
3rd vol.	2	16	0			
4th vol.	3	6	7			
5th vol.	4	3	2			
6th vol.	6	15	4			
7th vol.	7	9	0			
8th vol.	9	18	1			
9th vol.	20	15	0			
10th vol.	18	10	0			
11th vol.	34	6	11			
12th vol.	17	11	6			
Lithograph Signatures	0	6	0			
				131	8	11
Balance				478	1	5
				£2135	16	5

The General Treasurer on Account of the Printing

	£	s.	d.
To Cash received from Her Majesty's Government towards the expense of Printing the Catalogues of Stars of Lalande and Lacaille	1000	0	0
	£1000	0	0

British Association for the

	£	s.	d.
To Balance in hand of the Account for Printing Lalande and Lacaille's Catalogues	934	2	0
	£934	2	0

WM. YARRELL,
JAMES HEYWOOD, } *Auditors.*

ADVANCEMENT OF SCIENCE.

15th of August 1843 to the 26th of September 1844.

PAYMENTS.

	£	s.	d.	£	s.	d.
By Sundry Disbursements by Treasurer and Local Treasurers, including the Expenses of the Meeting at Cork, Advertising, and Sundry Printing				317	13	3
By Printing, &c. of the 12th Report (11th vol.)				344	3	6
By Engraving, &c. for the 13th Report (12th vol.)				42	7	0
By Salaries to Assistant General Secretary, Accountant, &c.				450	0	0
By Paid on Account of Grants to Committees for Scientific purposes, viz. for—						
Meteorological Observations at Kingussie and Inverness	12	0	0			
Completing.........ditto.........at Plymouth	35	0	0			
Magnetic and Meteorological Co-operation	25	8	4			
Publication of the British Association Catalogue of Stars	35	0	0			
Observations on Tides on the East Coast of Scotland	100	0	0			
Revision of the Nomenclature of Stars 1842	2	9	6			
Maintaining the Establishment in Kew Observatory	117	17	3			
Instruments for...........ditto...........ditto	56	7	3			
Influence of light on Plants	10	0	0			
Subterraneous Temperature in Ireland	5	0	0			
Coloured Drawings of Railway Sections	15	17	6			
Investigation of Fossil Fishes of the Lower Tertiary Strata	100	0	0			
Registering the Shocks of Earthquakes......1842	23	11	10			
Researches into the Structure of Fossil Shells	20	0	0			
Radiata and Mollusca of the Ægean and Red Seas ...1842	100	0	0			
Geographical distributions of Marine Zoology .... ,,	0	10	0			
Marine Zoology of Devon and Cornwall	10	0	0			
Do. ....Corfu	10	0	0			
Experiments on the Vitality of Seeds	9	0	3			
Ditto.................ditto......1842	8	7	3			
Researches on Exotic Anoplura	15	0	0			
Experiments on the Strength of Materials	100	0	0			
Completing Experiments on the Forms of Ships	100	0	0			
Inquiries into Asphyxia	10	0	0			
Investigations on the internal Constitution of Metals	50	0	0			
Constant Indicator and Morin's Instrument......1842	10	3	6			
				981	12	8
				£2135	16	5

of Lalande and Lacaille's Catalogues of Stars.

	£	s.	d.
By Cash paid on Account of Superintending the Press Work, &c. &c.	65	18	0
Balance	934	2	0
	£1000	0	0

Advancement of Science.

	£	s.	d.	£	s.	d.
By Balance due on the General Account				478	1	5
By Balance in the Bankers' hands	398	6	4			
Ditto......General Treasurer's hands	40	18	4			
Ditto......Local Treasurers' hands	16	15	10			
				456	0	7
				£934	2	0

The following Reports on the Progress and Desiderata of different branches of Science have been drawn up at the request of the Association, and printed in its Transactions.

1831–32.

On the progress of Astronomy during the present century, by G. B. Airy, M.A., Astronomer Royal.

On the state of our knowledge respecting Tides, by J. W. Lubbock, M.A., Vice-President of the Royal Society.

On the recent progress and present state of Meteorology, by James D. Forbes, F.R.S., Professor of Natural Philosophy, Edinburgh.

On the present state of our knowledge of the science of Radiant Heat, by the Rev. Baden Powell, M.A., F.R.S., Savilian Professor of Geometry, Oxford.

On Thermo-electricity, by the Rev. James Cumming, M.A., F.R.S., Professor of Chemistry, Cambridge.

On the recent progress of Optics, by Sir David Brewster, K.C.G., LL.D., F.R.S., &c.

On the recent progress and present state of Mineralogy, by the Rev. William Whewell, M.A., F.R.S.

On the progress, actual state, and ulterior prospects of Geology, by the Rev. William Conybeare, M.A., F.R.S., V.P.G.S., &c.

On the recent progress and present state of Chemical Science, by J. F. W. Johnston, A.M., Professor of Chemistry, Durham.

On the application of Philological and Physical Researches to the History of the Human Species, by J. C. Prichard, M.D., F.R.S., &c.

1833.

On the advances which have recently been made in certain branches of Analysis, by the Rev. G. Peacock, M.A., F.R.S., &c.

On the present state of the Analytical Theory of Hydrostatics and Hydrodynamics, by the Rev. John Challis, M.A., F.R.S., &c.

On the state of our knowledge of Hydraulics, considered as a branch of Engineering, by George Rennie, F.R.S., &c. (Parts I. and II.)

On the state of our knowledge respecting the Magnetism of the Earth, by S. H. Christie, M.A., F.R.S., Professor of Mathematics, Woolwich.

On the state of our knowledge of the Strength of Materials, by Peter Barlow, F.R.S.

On the state of our knowledge respecting Mineral Veins, by John Taylor, F.R.S., Treasurer G.S., &c.

On the Physiology of the Nervous System, by William Charles Henry, M.D.

On the recent progress of Physiological Botany, by John Lindley, F.R.S., Professor of Botany in the University of London.

1834.

On the Geology of North America, by H. D. Rogers, F.G.S.

On the Philosophy of Contagion, by W. Henry, M.D., F.R.S.

On the state of Physiological Knowledge, by the Rev. Wm. Clark, M.D., F.G.S., Professor of Anatomy, Cambridge.

On the state and progress of Zoology, by the Rev. Leonard Jenyns, M.A., F.L.S., &c.

On the theories of Capillary Attraction, and of the Propagation of Sound as affected by the Development of Heat, by the Rev. John Challis, M.A., F.R.S., &c.

On the state of the science of Physical Optics, by the Rev. H. Lloyd, M.A., Professor of Natural Philosophy, Dublin.

1835.

On the state of our knowledge respecting the application of Mathematical and Dynamical Principles to Magnetism, Electricity, Heat, &c., by the Rev. William Whewell, M.A., F.R.S.

On Hansteen's researches in Magnetism, by Captain Sabine, F.R.S.

On the state of Mathematical and Physical Science in Belgium, by M. Quetelet, Director of the Observatory, Brussels.

1836.

On the present state of our knowledge with respect to Mineral and Thermal Waters, by Charles Daubeny, M.D., F.R.S., M.R.I.A., &c., Professor of Chemistry and of Botany, Oxford.

On North American Zoology, by John Richardson, M.D., F.R.S., &c.

Supplementary Report on the Mathematical Theory of Fluids, by the Rev. J. Challis, Plumian Professor of Astronomy in the University of Cambridge.

1837.

On the variations of the Magnetic Intensity observed at different points of the Earth's surface, by Major Edward Sabine, R.A., F.R.S.

On the various modes of Printing for the use of the Blind, by the Rev. William Taylor, F.R.S.

On the present state of our knowledge in regard to Dimorphous Bodies, by Professor Johnston, F.R.S.

On the Statistics of the Four Collectorates of Dukhun, under the British Government, by Col. Sykes, F.R.S.

1838.

Appendix to Report on the variations of Magnetic Intensity, by Major Edward Sabine, R.A., F.R.S.

1839.

Report on the present state of our knowledge of Refractive Indices for the Standard Rays of the Solar Spectrum in different media, by the Rev. Baden Powell, M.A., F.R.S., F.G.S., F.R.Ast.S., Savilian Professor of Geometry, Oxford.

Report on the distribution of Pulmoniferous Mollusca in the British Isles, by Edward Forbes, M.W.S., For. Sec. B.S.

Report on British Fossil Reptiles, Part I., by Richard Owen, Esq., F.R.S., F.G.S., &c.

1840.

Report on the recent progress of discovery relative to Radiant Heat, supplementary to a former Report on the same subject inserted in the first volume of the Reports of the British Association for the Advancement of Science, by the Rev. Baden Powell, M.A., F.R.S., F.R.Ast.S., F.G.S., Savilian Professor of Geometry in the University of Oxford.

Supplementary Report on Meteorology, by James D. Forbes, Esq., F.R.S., Sec. R.S. Ed., Professor of Natural Philosophy in the University of Edinburgh.

1841.

Report on the Conduction of Heat, by Professor Kelland, F.R.S., &c.

Report on the state of our knowledge of Fossil Reptiles, Part II., by Professor R. Owen, F.R.S.

1842.

Abstract of Report of Professor Liebig on Organic Chemistry applied to Physiology and Pathology, by Lyon Playfair, M.D.

Report on the Ichthyology of New Zealand, by John Richardson, M.D., F.R.S.

Report on the Establishment of the German Meteorological Association, by Dr. Lamont of Munich.

Report on Chemical Geology, by Professor Johnston (Parts I. and II.).

Report on British Fossil Mammalia (Part I.), by Professor Owen.

1843.

Synoptical Table of British Fossil Fishes, by Professor Agassiz.

Report on British Fossil Mammalia (Part II.), by Professor Owen.

Report on the Fauna of Ireland (Invertebrata), by William Thompson, Esq.

1844.

On the recent Progress and present State of Ornithology, by H. E. Strickland, M.A., F.G.S.

The following Reports of Researches undertaken at the request of the Association have been published in its Transactions, viz.

1835.

On the comparative measurement of the Aberdeen Standard Scale, by Francis Baily, Treasurer R.S., &c.

On Impact upon Beams, by Eaton Hodgkinson.

Observations on the Direction and Intensity of the Terrestrial Magnetic Force in Ireland, by the Rev. H. Lloyd, Capt. Sabine, and Capt. J. C. Ross.

On the phænomena usually referred to the Radiation of Heat, by H. Hudson, M.D.

Experiments on Rain at different Elevations, by Wm. Gray, jun., and Professor Phillips (Reporter).

Hourly Observations of the Thermometer at Plymouth, by W. S. Harris.

On the Infra-orbital Cavities in Deers and Antelopes, by A. Jacob, M.D.

On the Effects of Acrid Poisons, by T. Hodgkin, M.D.

On the Motions and Sounds of the Heart, by the Dublin Sub-Committee.

On the Registration of Deaths, by the Edinburgh Sub-Committee.

1836.

Observations on the Direction and Intensity of the Terrestrial Magnetic Force in Scotland, by Major Edward Sabine, R.A., F.R.S., &c.

Comparative view of the more remarkable Plants which characterize the Neighbourhood of Dublin, the Neighbourhood of Edinburgh, and the South-west of Scotland, &c.; drawn up for the British Association by J. T. Mackay, M.R.I.A., A.L.S., &c.; assisted by Robert Graham, Esq., M.D., Professor of Botany in the University of Edinburgh.

Report of the London Sub-Committee of the Medical Section of the British Association on the Motions and Sounds of the Heart.

Report of the Dublin Committee on the Pathology of the Brain and Nervous System.

Account of the Recent Discussions of Observations of the Tides which have been obtained by means of the grant of money which was placed at the disposal of the Author for that purpose at the last Meeting of the Association, by J. W. Lubbock, Esq.

Observations for determining the Refractive Indices for the Standard Rays of the Solar Spectrum in various media, by the Rev. Baden Powell, M.A., F.R.S., Savilian Professor of Geometry in the University of Oxford.

Provisional Report on the Communication between the Arteries and Absorbents, on the part of the London Committee, by Dr. Hodgkin.

Report of Experiments on Subterranean Temperature, under the direction of a Committee, consisting of Professor Forbes, Mr. W. S. Harris, Professor Powell, Lieut-Colonel Sykes, and Professor Phillips (Reporter).

Inquiry into the validity of a method recently proposed by George B. Jerrard, Esq., for Transforming and Resolving Equations of Elevated Degrees; undertaken, at the request of the Association, by Professor Sir W. R. Hamilton.

1837.

Account of the Discussions of Observations of the Tides which have been obtained by means of the grant of money which was placed at the disposal of the Author for that purpose at the last Meeting of the Association, by J. W. Lubbock, Esq., F.R.S.

On the difference between the Composition of Cast Iron produced by the Cold and the Hot Blast, by Thomas Thomson, M.D., F.R.SS. L. & E., &c., Professor of Chemistry, Glasgow.

On the Determination of the Constant of Nutation by the Greenwich Observations, made as commanded by the British Association, by the Rev. T. R. Robinson, D.D.

On some Experiments on the Electricity of Metallic Veins, and the Temperature of Mines, by Robert Were Fox.

Provisional Report of the Committee of the Medical Section of the British Association, appointed to investigate the Composition of Secretions, and the Organs producing them.

Report from the Committee for inquiring into the Analysis of the Glands, &c. of the Human Body, by G. O. Rees, M.D., F.G.S.

Second Report of the London Sub-Committee of the Medical Section of the British Association, on the Motions and Sounds of the Heart.

Report from the Committee for making experiments on the Growth of Plants under Glass, and without any free communication with the outward air, on the plan of Mr. N. I. Ward of London.

Report of the Committee on Waves, appointed by the British Association at Bristol in 1836, and consisting of Sir John Robison, K.H., Secretary of the Royal Society of Edinburgh, and John Scott Russell, Esq., M.A., F.R.S. Edin. (Reporter).

On the Relative Strength and other Mechanical Properties of Cast Iron obtained by Hot and Cold Blast, by Eaton Hodgkinson, Esq.

On the Strength and other Properties of Iron obtained from the Hot and Cold Blast, by W. Fairbairn, Esq.

1838.

Account of a Level Line, measured from the Bristol Channel to the English Channel, during the year 1837–38, by Mr. Bunt, under the Direction of a Committee of the British Association. Drawn up by the Rev. W. Whewell, F.R.S., one of the Committee.

A Memoir on the Magnetic Isoclinal and Isodynamic Lines in the British Islands, from observations by Professors Humphrey Lloyd and John Phillips, Robert Were Fox, Esq., Captain James Clark Ross, R.N., and Major Edward Sabine, R.A., by Major Edward Sabine, R.A., F.R.S.

First Report on the Determination of the Mean Numerical Values of Railway Constants, by Dionysius Lardner, LL.D., F.R.S., &c.

First Report upon Experiments instituted at the request of the British Association, upon the Action of Sea and River Water, whether clear or foul, and at various temperatures, upon Cast and Wrought Iron, by Robert Mallet, M.R.I.A., Ass. Ins. C.E.

Notice of Experiments in progress, at the desire of the British Association, on the Action of a Heat of 212° Fahr., when long continued, on Inorganic and Organic Substances, by Robert Mallet, M.R.I.A.

Experiments on the ultimate Transverse Strength of Cast Iron made at Arigna Works, Co. Leitrim, Ireland, at Messrs. Bramah and Robinson's, 29th May, 1837.

Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals.

1839.

Report on the application of the sum assigned for Tide Calculations to Mr. Whewell, in a letter from T. G. Bunt, Esq., Bristol.

Notice of Determination of the Arc of Longitude between the Observatories of Armagh and Dublin, by the Rev. T. R. Robinson, D.D., &c.

Report of some Galvanic Experiments to determine the existence or nonexistence of Electrical Currents among Stratified Rocks, particularly those of the Mountain Limestone formation, constituting the Lead Measures of Alston Moor, by H. L. Pattinson, Esq.

Report respecting the two series of Hourly Meteorological Observations kept in Scotland at the expense of the British Association, by Sir David Brewster, K.H., LL.D., F.R.SS.L. and E.

Report on the subject of a series of Resolutions adopted by the British Association at their Meeting in August 1838, at Newcastle.

Third Report on the Progress of the Hourly Meteorological Register at the Plymouth Dockyard, Devonport, by W. Snow Harris, Esq., F.R.S.

1840.

Report on Professor Whewell's Anemometer, now in operation at Plymouth, by W. Snow Harris, Esq., F.R.S., &c.

Report on the Motions and Sounds of the Heart, by the London Committee of the British Association for 1839–40.

An Account of Researches in Electro-Chemistry, by Professor Schönbein of Basle.

Second Report upon the Action of Air and Water, whether fresh or salt, clear or foul, and at various temperatures, upon Cast Iron, Wrought Iron, and Steel, by Robert Mallet, M.R.I.A., Ass. Ins. C.E.

Report on the Observations recorded during the Years 1837, 1838, 1839 and 1840, by the Self-registering Anemometer erected at the Philosophical Institution, Birmingham, by A. Follett Osler, Esq.

Report respecting the two series of Hourly Meteorological Observations kept at Inverness and Kingussie, at the Expense of the British Association, from Nov. 1st, 1838, to Nov. 1st, 1839, by Sir David Brewster, K.H., F.R.S., &c.

Report on the Fauna of Ireland: Div. *Vertebrata*. Drawn up, at the request of the British Association, by William Thompson, Esq. (Vice-Pres. Nat. Hist. Society of Belfast), one of the Committee appointed for that purpose.

Report of Experiments on the Physiology of the Lungs and Air-tubes, by Charles J. B. Williams, M.D., F.R.S.

Report of the Committee appointed to try Experiments on the Preservation of Animal and Vegetable Substances, by the Rev. J. S. Henslow, F.L.S.

1841.

On the Tides of Leith, by the Rev. Professor Whewell, including a communication by D. Ross, Esq.

On the Tides of Bristol, by the Rev. Professor Whewell, including a communication by T. G. Bunt, Esq.

On Whewell's Anemometer, by W. S. Harris, Esq.

On the Nomenclature of Stars, by Sir John Herschel.

On the Registration of Earthquakes, by D. Milne, Esq.

On Varieties of the Human Race, by T. Hodgkin, M.D.

On Skeleton Maps for registering the geographical distribution of Animals or Plants, by — Brand, Esq.

On the Vegetative Power of Seeds, by H. E. Strickland, Esq.

On Acrid Poisons, by Dr. Roupell.

Supplementary Report on Waves, by J. S. Russell, Esq.

On the Forms of Ships, by J. S. Russell, Esq.

On the Progress of Magnetical and Meteorological Observations, by Sir John Herschel.

On Railway Constants, by Dr. Lardner.

On Railway Constants, by E. Woods, Esq.

On the Constant Indicator, by the Rev. Professor Moseley.

1842.

Results of Hourly Meteorological Observations at Inverness, from Nov. 1, 1840 to Nov. 1, 1841, by Sir David Brewster, K.H., F.R.S.

Second Report of the Committee for registering Earthquakes, by David Milne, Esq.

Results of Investigations on Waves, by John Scott Russell, M.A.

On the Progress of simultaneous Magnetical and Meteorological Observations, by Sir John Herschel.

On the Electrolysing Power of a simple Voltaic Circle, by Professor Schönbein.

Results of Researches on Marine Zoology by means of the dredge,—off the Mull of Galloway by Captain Beechy, R.N.,—off the Mull of Cantyre by Mr. Hyndman,—off Ballygally Head, Co. of Antrim, by Mr. Patterson.

On the Preservation of Animal and Vegetable Substances, by C. C. Babington, F.L.S.

Reports of Committee on Railway Sections, by Rev. Dr. Buckland and Mr. Vignoles.

On the Fishes of the Devonian Rocks and Old Red Sandstone, by M. Agassiz.

On the Growth and Vitality of Seeds, by H. E. Strickland, F.G.S.

On Zoological Nomenclature, by H. E. Strickland, F.G.S.

On the Races of Man, by T. Hodgkin, M.D.

On the Form of Ships, by John Scott Russell, M.A.

On the Constant Indicator, by Professor Moseley.

On the Meteorological Observations made at Plymouth during the past year, by William Snow Harris, F.R.S.

On Vital Statistics, by Colonel Sykes, and the Committee on that subject.

1843.

Third Report on the action of Air and Water on Iron and Steel, by R. Mallet, M.R.I.A.

Report of Committee for simultaneous Magnetic and Meteorological co-operation.

Report of Committee for Experiments on Steam-Engines.

Report of Committee for Experiments on the Vitality of Seeds.

Report on Tides of Frith of Forth and East coast of Scotland, by J. S. Russell, M.A.

Report of Committee on the Form of Ships.

Report on the Physiological Action of Medicines, by J. Blake, M.R.C.S.

Report of Committee on Zoological Nomenclature.

Report of Committee on Earthquakes.

Report of Committee on Balloons.

Report of Committee on Scientific Memoirs.

Report on Marine Testacea, by C. W. Peach,

Report on the Mollusca and Radiata of the Ægean Sea, by Professor E. Forbes.

Report of the Excavation at Collyhurst, near Manchester, by E. W. Binney.

Concluding Report of Railway Committee.

1844.

On the Microscopic Structure of Shells, by W. Carpenter, M.D., F.R.S.

Report on the British Nudibranchiate Mollusca, by Joshua Alder and Albany Hancock.

Researches on the Influence of Light on the Germination of Seeds and the Growth of Plants, by Robert Hunt.

Report of a Committee for revising the Nomenclature of the Stars.

On the Meteorology of Toronto in Canada, by Lieut.-Colonel Edward Sabine, R.A., F.R.S.

Report on some recent Researches into the Structure, Functions and Œconomy of the *Araneidea*, made in Great Britain by John Blackwall, F.L.S.

On the Construction of large Reflecting Telescopes, by the Earl of Rosse.

Report on a Gas Furnace for Experiments on Vitrifaction and other Applications of High Heat in the Laboratory, by the Rev. William Vernon Harcourt, F.R.S., &c.

Report of Committee for registering Earthquake Shocks in Scotland.

Report of Committee for Experiments on Steam-Engines.

Report of Committee to investigate the Varieties of the Human Race.

Report of Committee for Experiments on the Vitality of Seeds.

On the Consumption of Fuel and the Prevention of Smoke, by William Fairbairn.

Report concerning the Observatory of the British Association at Kew, from August the 1st, 1843, to July the 31st, 1844, by Francis Ronalds, F.R.S.

Report of Committee for simultaneous Magnetic and Meteorological co-operation.

On the influence of Fucoidal Plants upon the Formations of the Earth, on Metamorphism in general, and particularly the Metamorphosis of the Scandinavian Alum Slate, by Professor G. Forchhammer.

Report on Subterranean Temperature in Ireland, by T. Oldham, Esq.

Report on the extinct Mammals of Australia, with descriptions of certain Fossils indicative of the former existence in that Continent of large Marsupial Representatives of the Order Pachydermata, by Professor Owen, F.R.S.

Report on the Working of Whewell's and Osler's Anemometers at Plymouth, for the years 1841, 1842, 1843, by W. Snow Harris, F.R.S., &c.

Report on Atmospheric Waves, by W. R. Birt.

Rapport sur les Poissons Fossiles de l'Argile de Londres, par L. Agassiz.

Report of Committee on Waves, by J. S. Russell, M.A., F.R.S.E.

Provisional Reports and Notices of Progress in Special Researches entrusted to Committees and Individuals.

RECOMMENDATIONS ADOPTED BY THE GENERAL COMMITTEE AT THE YORK MEETING IN SEPT. AND OCT. 1844.

Recommendations for Reports and Researches not involving Grants of Money.

That the Thanks of the British Association be given to Her Majesty's Government for their prompt and liberal acquiescence in the request of the Association for the publication of Mr. Forbes's Ægean Researches at the public cost.

That a representation be made to Her Majesty's Government on the importance of providing adequate funds for the development of the Cautley Collection of Siwalik Fossils, and publication of an account of the same. The representation to be made by a Committee consisting of the President of the British Association, the President of the Royal Society, the President of the Geological Society, in co-operation with the President of the Royal Asiatic Society.

That, in consequence of the difficulty, delay, and expense which attend the transmission of Scientific Journals between the British Isles and foreign countries, an application be made to Government by the President and General Secretaries, to take the subject into its favourable consideration.

That the Dean of Ely be requested to accept the office of a Trustee of the Association, in the room of F. Baily, Esq. deceased.

That Sir John Herschel, the Astronomer Royal, and Lieut. Stratford, R.N., be requested to continue the Reduction of Stars in the 'Histoire Céleste' of Lalande and the 'Cœlum Australe Stelliferum' of Lacaille.

That Sir D. Brewster be requested to continue his investigations on the action of different bodies on the Spectrum.

That Col. Sabine, Professor Wheatstone, Prof. Miller and Prof. Graham, be a Committee for superintending the translation and publication of Scientific Memoirs.

That Col. Sabine's Paper 'On the Meteorology of Toronto' be published entire among the Reports.

That Professor Schönbein be requested to prepare a Report on Ozone.

That Professor Kuhlman of Lille, be requested to extend his Researches on the Silicification of soft Minerals.

That Dr. Forchhammer's Paper on the influence of fucoidal Plants in the formation of strata and on the Metamorphic Phænomena in the Rocks of Scandinavia, be printed entire among the Reports.

That Mr. West be requested to extend his analysis of English Mineral Waters, and report the results.

That H. Goodsir, Esq. be requested to prepare a Report on the Cirripeda.

That G. J. Johnston, M.D. be requested to prepare a Report on the British Annelida.

That J. Paxton, Esq., J. Taylor, jun., Esq., J. S. Russell, Esq., and E. Hodgkinson, Esq., be requested to make and report the results of Experiments on the Hydrodynamical Phænomena of the Reservoir and Fountain at Chatsworth.

That E. Hodgkinson, Esq. be requested to continue his Experiments on the Strength of Materials.

That W. Fairbairn, Esq. be requested to continue his Experiments on the Internal Constitution of Metals.

That the Meteorological Observations made at the request of the Association be discontinued, and the instruments transmitted to the Kew Physical Observatory, except in the cases where the observations can be continued gratuitously.

That the Council be authorized to invite, in the name of the British Association, the attendance of MM. Humboldt, Gauss, Weber, Kupffer, Arago, Plana, Hansteen, Kreil, Lamont, Boguslawski, Gillip, Quetelet, and other distinguished foreigners who have taken a leading part in the great combined system of magnetic and meteorological observations which are now in progress, at the next Meeting of the Association at Cambridge, with a view to a conference on the expediency of continuing the observations for another triennial or longer period, and for the adoption of such measures with respect to the observations which have been or may hereafter be made, as they may deem best calculated to promote the advancement of those branches of Science.

That Mr. Bateman, C.E. of Manchester, be requested to furnish a Report on the fall of rain in elevated tracts of country, and on the best means of collecting and retaining the water for the supply of towns for agricultural and manufacturing purposes, and for affording motive power to hydraulic machines.

That it be referred to the Council to consider of the propriety of modifying the title and regulations of Section E, so that it may include a more general range of subjects, and to report on the best mode of carrying that modification into effect.

Recommendations of Special Researches in Science, involving Grants of Money.

MATHEMATICAL AND PHYSICAL SCIENCE.

That a Committee be appointed, consisting of the Rev. Dr. Robinson, Prof. Challis, and Lieut. Stratford, R.N., for the purpose of continuing the publication of the British Association Catalogue of Stars, with the sum of £615 at their disposal.

That a Committee be appointed, consisting of Rev. Dr. Robinson, Col. Sabine, and Prof. Wheatstone, for the purpose of conducting experiments with Captive Balloons, with the sum of £50 at their disposal.

That a Committee be appointed, consisting of Sir John F. W. Herschel, Rev. Dr. Whewell, the Dean of Ely, the Astronomer Royal, Rev. Dr. Lloyd, and Col. Sabine, for the purpose of Magnetic and Meteorological co-operation, with the sum of £50 at their disposal.

That a Committee be appointed, consisting of Sir John Herschel, the Rev. Dr. Whewell, and the Astronomer Royal, for the purpose of revising the Nomenclature of Stars, with the sum of £10 at their disposal.

That a Committee be appointed, consisting of F. Ronalds, Esq., Prof. Wheatstone, and the Astronomer Royal, for the purpose of conducting the Electrical Experiments at Kew, with the sum of £50 at their disposal.

That a Committee be appointed, consisting of W. S. Harris, Esq., Col. Sabine, and Prof. Forbes, for the purpose of reducing the existing anemometrical observations made at the request of the Association, with the sum of £25 at their disposal.

That the Bills for Meteorological Instruments due to Mr. Adie and Mr. Johnstone of Edinburgh, amounting to £18 12*s.* 6*d.*, be discharged.

That the sum of £57 be placed at the disposal of the Council for the payment of expenses incurred in the provision of electrical apparatus for the Kew Physical Observatory.

KEW OBSERVATORY.

That the sum of £150 be placed at the disposal of the Council for the purpose of maintaining the establishment in Kew Observatory.

That the sum of £30 be placed at the disposal of the Council for the erection of Kreil's Barometrograph at the Kew Observatory.

CHEMICAL SCIENCE.

That a Committee be appointed, consisting of Prof. Graham, Dr. Lyon Playfair, and Mr. E. Solly, for the purpose of analysing the ashes of Plants grown on different soils in the British Islands, and reporting the results, in case the Royal Agricultural Society of England concurs with the Association in making the request and is willing to contribute to the expense, with (in that case) the sum of £50 at their disposal.

That this Resolution be communicated to the Royal Agricultural Society, and that they be requested to co-operate with the British Association in conducting the inquiries, and to assist in defraying the expense of the analyses.

That the Marquis of Northampton, and Sir J. Johnstone, be requested to press this subject upon the attention of the Royal Agricultural Society.

That a Committee be appointed, consisting of Prof. Bunsen and Dr. Lyon Playfair, for the purpose of continuing their researches on the Gases evolved from Furnaces used in the manufacture of iron, and reporting thereon, with the sum of £50 at their disposal.

That a Committee be appointed, consisting of Dr. Daubeny, Dr. Kane, Dr. Apjohn, Mr. Ball, Mr. Babington, Prof. Owen, Prof. Forbes, and Mr. Goadby, for the purpose of continuing examinations into the best method of preserving Vegetable and Animal Substances, with the sum of £10 at their disposal.

That Dr. Kane be requested to continue his researches on Tannin, and report thereon to the next Meeting, with £10 at his disposal for the purpose.

That Dr. Kane be requested to continue his researches into the nature of Colouring Substances, and report thereon to the next Meeting, with £10 at his disposal for the purpose.

That Mr. R. Hunt be requested to institute experiments on the Actinograph, with £15 at his disposal for the purpose.

GEOLOGICAL SCIENCE.

That Mr. Oldham be requested to continue his observations on Subterranean Temperature in deep mines in Ireland for one year, with £5 at his disposal for the purpose.

GEOLOGY AND ZOOLOGY.

That Dr. W. Carpenter be requested to continue his Microscopic Researches into the Structure of Recent and Fossil Shells, &c., with £20 at his disposal for the purpose.

That Dr. Carpenter's Report on the Microscopic Structure of Shells be illustrated by Lithographic Plates not exceeding twenty in number.

BOTANY AND ZOOLOGY.

That a Committee be appointed, consisting of Professor Owen, Prof. E. Forbes, Dr. Lankester, Mr. R. Taylor, Mr. Thompson, Mr. Ball, Prof. Allman, Mr. Hugh E. Strickland, and Mr. Babington, for the purpose of preparing a Report on the registration of periodical phænomena of animals and vegetables, with the sum of £5 at their disposal for the purpose.

That a Committee be appointed, consisting of Sir W. Jardine, Mr. Yarrell, and Dr. Lankester, for the purpose of continuing their researches on the Exotic Anoplura, and reporting the results to the next Meeting, with the sum of £25 at their disposal.

That a Committee be appointed, consisting of Mr. H. E. Strickland, Dr. Daubeny, Dr. Lindley, Prof. Balfour, and Mr. Babington, for the purpose of continuing researches on the Vitality of Seeds, with the sum of £10 at their disposal.

That a Committee be appointed, consisting of Prof. Forbes, Mr. Thompson, and Mr. Ball, for the purpose of assisting Capt. Portlock in investigating the Marine Zoology of Corfu, with the sum of £10 at their disposal.

That a Committee be appointed, consisting of Prof. Forbes, Mr. Goodsir, Mr Patterson, Mr. Thompson, Mr. Ball, Mr. J. Smith, Mr. Couch, and Dr. Allman, for the purpose of continuing their investigations of the Marine Zoology of Britain by means of the dredge, with the sum of £20 at their disposal.

That a Committee be appointed, consisting of Prof. Owen, Prof. Forbes, Sir C. Lemon, and Mr. Couch, for the purpose of aiding Mr. Peach in his researches into the Marine Zoology of Cornwall, with the sum of £10 at their disposal.

That a Committee be appointed, consisting of Dr. Hodgkin, Dr. Prichard, Prof. Owen, Dr. H. Ware, Mr. J. E. Gray, Dr. Lankester, Dr. A. Smith, Mr. A. Strickland, and Mr. Babington, for the purpose of continuing researches on the varieties of the Human Race, with the sum of £25 at their disposal.

MEDICAL SCIENCE.

That a Committee be appointed, consisting of Mr. Blake, and Dr. Williams, for the purpose of reporting on the Physiological Action of Medicines, with the sum of £20 at their disposal.

STATISTICAL SCIENCE.

That a Committee be appointed, consisting of Dr. Laycock, Dr. Alison, and Mr. E. Chadwick, for the purpose of inquiring into the relative Statistics of Sickness and Mortality in the city of York, with the sum of £40 at their disposal.

GENERAL NOTICE.

Gentlemen engaged in scientific researches by desire of the British Association, are requested to observe that by a Resolution of the General Committee at the Manchester Meeting (1842), all Instruments, Papers, Drawings and other property of the Association, are to be deposited in the Kew Observatory (lately placed by Her Majesty the Queen at the disposal of the Association), when not employed in carrying on Scientific Inquiries for the Association; and the Secretaries are instructed to adopt the necessary measures for carrying this resolution into effect.

Synopsis of Grants of Money appropriated to Scientific Objects by the General Committee, at the York Meeting, October 2, 1844, with the Name of the Member, who alone, or as the First of a Committee, is entitled to draw for the Money.

Mathematical and Physical Science.

	£	s.	d.
Robinson, Dr.—For the Publication of the British Association Catalogue of Stars	615	0	0
Robinson, Dr.—For conducting experiments with Captive Balloons	50	0	0
Herschel, Sir J.—For Magnetic and Meteorological Co-operation	50	0	0
Harris, W. S.—For Reduction of Anemometrical Observations	25	0	0
Herschel, Sir J.—For Nomenclature of Stars	10	0	0
Ronalds, F., Esq.—For Electrical Experiments at Kew	50	0	0
Expenses Incurred.—For continuing hourly Meteorological Observations at Inverness	30	18	11
—— For Meteorological Instruments at Edinburgh	18	12	6
—— For Electrical Apparatus at Kew	57	0	0
	£906	11	5

Kew Observatory.

For maintaining the establishment in Kew Observatory	150	0	0
For Kreil's Barometrograph	30	0	0
	£180	0	0

Chemistry and Mineralogy, including their application to Agriculture and the Arts.

Bunsen, Professor.—For Gases from Iron Furnaces	50	0	0
Daubeny, Dr.—For Preservation of Animal and Vegetable Substances	10	0	0
Kane, Professor.—For inquiries into the Chemical History of Tannin	10	0	0
Kane, Professor.—For investigating the Chemical History of Colouring Matter	10	0	0
Hunt, R., Esq.—For Experiments on the Actinograph	15	0	0
Graham, Professor.—For Ashes of Plants	50	0	0
	£145	0	0

Geology and Physical Geography.

Oldham, T., Esq.—For experiments on Subterraneous Temperature in Ireland	5	0	0
Carpenter, Dr.—For Researches into the Microscopic Structure of Fossil and Recent Shells, &c.	20	0	0
	£25	0	0

Zoology and Botany.

	£	s.	d.
Owen, Professor.—For Periodical Phænomena of Organized Beings	5	0	0
Jardine, Sir W., Bart.—For Researches on Exotic Anoplura	25	0	0
Strickland, H. E., Esq.—For Experiments on the Vitality of Seeds	10	0	0
Portlock, Captain.—For a Report on the Marine Zoology of Corfu	10	0	0
Forbes, Professor E.—For Researches on the Marine Zoology of Britain	20	0	0
Owen, Professor.—For Researches on the Marine Zoology of Cornwall	10	0	0
Hodgkin, Dr.—For Inquiries into the Varieties of the Human Race	25	0	0
	£105	0	0

Medical Science.

	£	s.	d.
Blake, J., Esq.—For Physiological Action of Medicines	£20	0	0

Statistics.

	£	s.	d.
Laycock, Dr.—For Statistics of Sickness and Mortality in York	£40	0	0
Total of Grants	£1421	11	5

General Statement of Sums which have been paid on Account of Grants for Scientific Purposes.

1834.

	£	s.	d.
Tide Discussions	20	0	0

1835.

	£	s.	d.
Tide Discussions	62	0	0
British Fossil Ichthyology	105	0	0
	£167	0	0

1836.

	£	s.	d.
Tide Discussions	163	0	0
British Fossil Ichthyology	105	0	0
Thermometric Observations, &c.	50	0	0
Experiments on long-continued Heat	17	1	0
Rain Gauges	9	13	0
Refraction Experiments	15	0	0
Lunar Nutation	60	0	0
Thermometers	15	6	0
Carried forward	£435	0	0

1837.

	£	s.	d.
Brought forward	435	0	0
Tide Discussions	284	1	0
Chemical Constants	24	13	6
Lunar Nutation	70	0	0
Observations on Waves	100	12	0
Tides at Bristol	150	0	0
Meteorology and Subterranean Temperature	89	5	0
Vitrification Experiments	150	0	0
Heart Experiments	8	4	6
Barometric Observations	30	0	0
Barometers	11	18	6
	£918	14	6

1838.

	£	s.	d.
Tide Discussions	29	0	0
British Fossil Fishes	100	0	0
Carried forward	£129	0	0

	£	s.	d.
Brought forward	129	0	0
Meteorological Observations and Anemometer (construction)	100	0	0
Cast Iron (strength of)	60	0	0
Animal and Vegetable Substances (preservation of)	19	1	10
Railway Constants	41	12	10
Bristol Tides	50	0	0
Growth of Plants	75	0	0
Mud in Rivers	3	6	6
Education Committee	50	0	0
Heart Experiments	5	3	0
Land and Sea Level	267	8	7
Subterranean Temperature	8	6	0
Steam-vessels	100	0	0
Meteorological Committee	31	9	5
Thermometers	16	4	0
	£956	12	2

1839.

	£	s.	d.
Fossil Ichthyology	110	0	0
Meteorological Observations at Plymouth	63	10	0
Mechanism of Waves	144	2	0
Bristol Tides	35	18	6
Meteorology and Subterranean Temperature	21	11	0
Vitrification Experiments	9	4	7
Cast Iron Experiments	100	0	0
Railway Constants	28	7	2
Land and Sea Level	274	1	4
Steam-Vessels' Engines	100	0	0
Stars in Histoire Céleste	331	18	6
Stars in Lacaille	11	0	0
Stars in R.A.S. Catalogue	6	16	6
Animal Secretions	10	10	0
Steam-engines in Cornwall	50	0	0
Atmospheric Air	16	1	0
Cast and Wrought Iron	40	0	0
Heat on Organic Bodies	3	0	0
Gases on Solar Spectrum	22	0	0
Hourly Meteorological Observations, Inverness and Kingussie	49	7	8
Carried forward	£1427	8	3

	£	s.	d.
Brought forward	1427	8	3
Fossil Reptiles	118	2	9
Mining Statistics	50	0	0
	£1595	11	0

1840.

	£	s.	d.
Bristol Tides	100	0	0
Subterranean Temperature	13	13	6
Heart Experiments	18	19	0
Lungs Experiments	8	13	0
Tide Discussions	50	0	0
Land and Sea Level	11	6	1
Stars (Histoire Céleste)	242	10	0
Stars (Lacaille)	4	15	0
Stars (Catalogue)	264	0	0
Atmospheric Air	15	15	0
Water on Iron	10	0	0
Heat on Organic Bodies	7	0	0
Meteorological Observations	32	17	6
Foreign Scientific Memoirs	112	1	6
Working Population	100	0	0
School Statistics	50	0	0
Forms of Vessels	184	7	0
Chemical and Electrical Phænomena	40	0	0
Meteorological Observations at Plymouth	80	0	0
Magnetical Observations	185	13	0
	£1546	16	4

1841.

	£	s.	d.
Observations on Waves	30	0	0
Meteorology and Subterranean Temperature	8	8	0
Actinometers	10	0	0
Earthquake Shocks	17	7	0
Acrid Poisons	6	0	0
Veins and Absorbents	3	0	0
Mud in Rivers	5	0	0
Marine Zoology	15	12	8
Skeleton Maps	20	0	0
Mountain Barometers	6	18	6
Stars (Histoire Céleste)	185	0	0
Stars (Lacaille)	79	5	0
Stars (Nomenclature of)	17	19	6
Stars (Catalogue of)	40	0	0
Water on Iron	50	0	0
Carried forward	£494	10	8

	£	s.	d.
Brought forward	494	10	8
Meteorological Observations at Inverness ..	20	0	0
Meteorological Observations (reduction of) ..	25	0	0
Fossil Reptiles	50	0	0
Foreign Memoirs	62	0	0
Railway Sections	38	1	6
Forms of Vessels	193	12	0
Meteorological Observations at Plymouth ..	55	0	0
Magnetical Observations	61	18	8
Fishes of the Old Red Sandstone	100	0	0
Tides at Leith........	50	0	0
Anemometer at Edinburgh	69	1	10
Tabulating Observations	9	6	3
Races of Men	5	0	0
Radiate Animals	2	0	0
	£1235	10	11

1842.

	£	s.	d.
Dynamometric Instruments	113	11	2
Anoplura Britanniæ ..	52	12	0
Tides at Bristol	59	8	0
Gases on Light	30	14	7
Chronometers	26	17	6
Marine Zoology	1	5	0
British Fossil Mammalia	100	0	0
Statistics of Education..	20	0	0
Marine Steam-vessels' Engines	28	0	0
Stars (Histoire Céleste).	59	0	0
Stars (British Association Catalogue of) ..	110	0	0
Railway Sections	161	10	0
British Belemnites	50	0	0
Fossil Reptiles (publication of Report)	210	0	0
Forms of Vessels	180	0	0
Galvanic Experiments on Rocks	5	8	6
Meteorological Experiments at Plymouth ..	68	0	0
Constant Indicator and Dynamometric Instruments	90	0	0
Force of Wind	10	0	0
Carried forward	£1376	6	9

	£	s.	d.
Brought forward	1376	6	9
Light on Growth of Seeds	8	0	0
Vital Statistics	50	0	0
Vegetative Power of Seeds	8	1	11
Questions on Human Race	7	9	0
	£1449	17	8

1843.

	£	s.	d.
Revision of the Nomenclature of Stars	2	0	0
Reduction of Stars, British Association Catalogue	25	0	0
Anomalous Tides, Frith of Forth	120	0	0
Hourly Meteorological Observations at Kingussie and Inverness.	77	12	8
Meteorological Observations at Plymouth ..	55	0	0
Whewell's Meteorological Anemometer at Plymouth	10	0	0
Meteorological Observations, Osler's Anemometer at Plymouth ..	20	0	0
Reduction of Meteorological Observations ..	30	0	0
Meteorological Instruments and Gratuities.	39	6	0
Construction of Anemometer at Inverness ..	56	12	2
Magnetic Co-operation .	10	8	10
Meteorological Recorder for Kew Observatory	50	0	0
Action of Gases on Light	18	16	1
Establishment at Kew Observatory, Wages, Repairs, Furniture, and Sundries	133	4	7
Experiments by Captive Balloons	81	8	0
Oxidations of the Rails of Railways	20	0	0
Publication of Report on Fossil Reptiles	40	0	0
Coloured Drawings of Railway Sections....	147	18	3
Carried forward	£937	6	7

	£	s.	d.
Brought forward	937	6	7
Registration of Earthquake Shocks	30	0	0
Uncovering Lower Red Sandstone near Manchester	4	4	6
Report on Zoological Nomenclature	10	0	0
Vegetative Power of Seeds	5	3	8
Marine Testacea (Habits of)	10	0	0
Marine Zoology	10	0	0
Marine Zoology	2	14	11
Preparation of Report on British Fossil Mammalia	100	0	0
Physiological operations of Medicinal Agents	20	0	0
Vital Statistics	36	5	8
Additional Experiments on the Forms of Vessels	70	0	0
Additional Experiments on the Forms of Vessels	100	0	0
Reduction of Observations on the Forms of Vessels	100	0	0
Morin's Instrument and Constant Indicator	69	14	10
Experiments on the Strength of Materials	60	0	0
	£1565	10	2
Kew Observatory Establishment	150	0	0
Kreil's Barometrograph	30	0	0
British Association Catalogue of Stars	615	0	0
Captive Balloons	50	0	0
Meteorological Observation at Inverness	30	18	11
Carried forward	£875	18	11

	£	s.	d.
Brought forward	875	18	11
Magnetic and Meteorological Co-operation	50	0	0
Meteorological Instruments at Edinburgh	18	12	6
Reduction of Anemometrical Observations	25	0	0
Nomenclature of Stars	10	0	0
Electrical Experiments at Kew	50	0	0
Electrical Apparatus	57	0	0
Gases from Iron Furnaces	50	0	0
Preservation of animal and vegetable Substances	10	0	0
Report on Tannin	10	0	0
On Colouring Matter	10	0	0
Experiments on the Actinograph	15	0	0
Ashes of Plants	50	0	0
Subterranean Temperature in Ireland	5	0	0
Microscopic Structure of Shells, &c.	20	0	0
Periodical Phænomena of Organized Beings	5	0	0
Exotic Anoplura	25	0	0
Vitality of Seeds	10	0	0
Zoology of Corfu	10	0	0
Marine Zoology of Britain	20	0	0
Marine Zoology of Cornwall	10	0	0
Varieties of the Human Race	25	0	0
Physiological Action of Medicines	20	0	0
Statistics of Sickness and Mortality in York	40	0	0
	£1421	11	5

Extracts from Resolutions of the General Committee.

Committees and individuals to whom grants of money for scientific purposes have been entrusted, are required to present to each following meeting of the Association a Report of the progress which has been made; with a statement of the sums which have been expended, and the balance which remains disposable on each grant.

Grants of pecuniary aid for scientific purposes from the funds of the Association expire at the ensuing meeting, unless it shall appear by a Report that the Recommendations have been acted on, or a continuation of them be ordered by the General Committee.

In each Committee, the Member first named is the person entitled to call on the Treasurer, John Taylor, Esq., 2 Duke Street, Adelphi, London, for such portion of the sum granted as may from time to time be required.

In grants of money to Committees, the Association does not contemplate the payment of personal expenses to the Members.

In all cases where additional grants of money are made for the continuation of Researches at the cost of the Association, the sum named shall be deemed to include, as a part of the amount, the specified balance which may remain unpaid on the former grant for the same object.

On Thursday evening, September 26th, at 8 P.M., in the Festival Concert Room, York, the late President, the Earl of Rosse, resigned his office to the Very Rev. the Dean of Ely, who took the Chair at the General Meeting, and delivered an Address, for which see p. xxxi.

On Friday evening, September 27th, in the same room, Charles Lyell, Esq., F.R.S., delivered a Discourse on the Geology of North America, particularly noticing the latest surveys of the Western Coal-fields of the United States, and new facts which had been discovered, bearing on the recession of the Falls of Niagara. The discourse was illustrated by Diagrams and other drawings.

On Saturday evening, September 28th, in the same room, Dr. Falconer, F.G.S., delivered a Discourse on the Gigantic Tortoise of the Siwalik Hills in India, illustrated by a restoration drawing of the full size (20 feet) and specimens of particular bones of the fossil.

On Wednesday evening, October 2nd, at 8 P.M., in the same room, the Concluding General Meeting of the Association was held, when the Proceedings of the General Committee, and the grants of money for scientific purposes, were explained to the Members.

ADDRESS

BY

THE VERY REV. GEORGE PEACOCK, D.D.,

DEAN OF ELY, F.R.S., F.R.A.S., &C.

Gentlemen,—The Noble Lord to whose office I succeed, and who has introduced me to your notice, has spoken of me in terms which, however flattering to my pride, I can only accept as the expression of his friendship and good will; and I hope he will permit me to add, that whilst there are few persons for whose character and attainments I feel a more sincere respect, there is none whose favourable opinion I should be more anxious to merit. The Members of the Association who were present at the Meeting at Cork, can bear witness to the courteous, dignified and able manner in which he discharged the duties of his office; whilst others who, like myself, had the opportunity of seeing them, could not fail to be deeply impressed with the magnificent works which are accomplished, or in progress, at his noble residence at Birr Castle. Whatever met the eye was upon a gigantic scale: telescopic tubes, through which the tallest man could walk upright; telescopic mirrors, whose weights are estimated not by pounds but by tons, polished by steam power with almost inconceivable ease and rapidity, and with a certainty, accuracy and delicacy exceeding the most perfect production of the most perfect manipulation; structures of solid masonry for the support of the telescope and its machinery more lofty and massive than those of a Norman keep; whilst the same arrangements which secure the stability of masses which no ordinary crane could move, provide likewise for their obeying the most delicate impulse of the most delicate finger, or for following the stars in their course, through the agency of clockwork, with a movement so steady and free from tremors, as to become scarcely perceptible when increased one thousand-fold by the magnifying powers of the eye-glass.

The instruments, which were mounted and in operation at the time of my visit, exceeded in optical power and in the clearness and precision of their definition of celestial objects, the most perfect productions of the greatest modern artists; and though much had been then accomplished, and great difficulties had been overcome by a rare combination of mechanical, chemical and mathematical skill and knowledge in the preparation for mounting the great telescope of six feet diameter and fifty-four feet focal length, yet much remained to be done; but I am quite sure that the Members of the Association will learn with unmixed satisfaction that the Noble Lord has entirely succeeded in his great undertaking; that the great telescope has already made its first essay, and that its performance is in every way satisfactory; and that he proposes to communicate to the Mathematical and Physical Section, in the course of the present Meeting, an account of the process which he has followed in the preparation and polishing of his mirrors, and of the expedients which he has adopted for bringing under the most perfect control the movements of the vast masses with which he has had to deal.

It is now more than sixty years since the elder Herschel, by the superior optical and space-penetrating powers of his telescopes, began a brilliant career of astronomical discovery, and the interest which the construction of his great forty-foot reflector—a memorable monument of his perseverance, genius and skill—excited amongst men of science of that period, was, if possible, not less intense than what now attaches to the similar enterprise of the Noble Lord: nor were the expectations which were thus raised disappointed by the result; for though this noble instrument was generally reserved for the great and state occasions of astronomy only, requiring too great an expenditure of time and labour to be conveniently producible for the daily and ordinary business of observation, yet the very first time it was directed to the heavens it discovered the seventh satellite of Saturn, and contributed in no inconsiderable degree to the more complete developement of those views of the construction of the heavens (I use his own expression), which his contemporaries never sufficiently appreciated, but which present and future ages will probably regard as the most durable monument of his fame.

It is no derogation to the claims of this great discoverer that art and knowledge are progressive, or that a successor should have arisen, who, following in the track which he has pointed out, should bring a coordinate zeal and more ample means to prepare the way for another great epoch in the history of astronomical discovery; and I know that I do not mistake the sentiments of the accomplished philosopher who has succeeded to his name and honours, and who throughout his life has laboured with such exemplary filial piety and such distinguished success in the developement and extension of his father's views, that no one takes a deeper or more lively interest in the success of this noble enterprise, and no one rejoices more sincerely in the vast prospects of discovery which it opens.

Gentlemen, it is now thirteen years since the British Association held its first Meeting in this ancient and venerable city, under the presidency of the Noble Earl Fitzwilliam, who is always the first to offer his services in the promotion of the interests of science and of every good and useful undertaking. It was in this city that its constitution and laws were first organized, and it is by these laws, for which we are chiefly indebted to the excellent sense and judgement of Mr. William Vernon Harcourt, with very unimportant changes, the Association has continued to be governed. It is in conformity with the spirit of these laws that we should seek to cooperate, and not to interfere, with other societies which have pursuits and objects in common with our own; that we should claim no right to the publication of Memoirs which are read at our Sections, and which are not prepared at our request; that we should endeavour to concentrate and direct the influence of the public opinion of men engaged or interested in the pursuits of science in favour of such objects, and such objects only, as they agree in considering important for its interests; and, above all, that we should avail ourselves of the advantages which we possess, in the extensive range of our operations, and in our independence of particular societies and particular localities, of organizing and carrying into effect well-digested systems of cooperative labour.

Again, our Meetings were also designed to bring men who are engaged in common pursuits and interested in common objects into closer union and more frequent intercourse with each other; to encourage the more humble and less generally known cultivators of science, by bringing their labours under the notice of those men who are best able to appreciate and to give currency to their value; to enable our Members to see us in the places which they visited,—where all establishments are, with rare exceptions, most liberally thrown open to their inspection,—whatever is most remarkable in the productions of their manufactures, in the principles and construction of their machinery, in their collections connected with art or the natural sciences, in their public establishments for charity or education, in the moral or physical condition of their inhabitants, or whatever other objects their neighbourhood presents which may interest the antiquary, the geologist, or the lover of picturesque scenery. We may venture to add, likewise, that they were designed for purposes of social as well as of philosophical recreation,—a consideration of no small importance with men whose occupations are frequently monotonous and laborious, and such as require the occasional stimulus of change and variety.

In accordance with these views, we have visited, in their turn, the most remarkable localities of the three kingdoms, including the universities of England, Scotland and Ireland, the great seats of our manufacturing industry, the great marts of our commerce; and it is not necessary for me to speak of the success which has marked our progress. The numbers who have attended our Meetings have been always large, and sometimes so great as to embarrass our proceedings from the difficulty of finding adequate rooms to receive them; the communications which have come under the notice of our several Sections have continued to increase in importance and interest, more particularly since the great cooperative inquiries of our body have come into full operation. We have been enabled, by the application of our funds, to complete some and to forward many scientific enterprises of the highest importance and value, and I see no reason to apprehend that the future Meetings of the British Association will not continue to advance in scientific interest, or cease to exercise a most powerful influence in originating and promoting scientific labours, which will equally tend to promote the interests of knowledge and the honour of the empire.

The founders of the British Association justly conceived that men of different shades of political opinion or religious belief would rejoice in the opportunities which such Meetings would afford them of coming together, as it were, upon neutral ground, where their mutual warfare would, for a season at least, be suspended, and no sounds be heard but those of peace: they felt persuaded that the softening influence of reciprocal intercourse would tend to soothe the bitterness of party strife, and would expose to view points of contact and union even between those whom circumstances had most violently estranged from each other, and show them that the features of the monsters of their apprehension were not so repulsive as their imaginations or intolerance had drawn them. I know that there are some zealots who are ready to denounce the interchange of the commonest charities of life with those whose opinions, however honestly and conscientiously formed, they believe to be unfounded or dangerous. But there is a wide and fundamental distinction between the condemnation of opinions and of the persons who hold them; and though I should be far from advocating that spurious and false liberality which should assume that in the selection of friends, or even in the ordinary intercourse of society, there should be a total suppression of all that is distinctive, both of profession and of opinion, yet there are numberless occasions on which we can neither notice them or know of their existence without the violation of all those rules of courtesy and good breeding which the most scrupulous regard for the integrity of our christian profession and for the best interests of mankind would equally teach us to practise and to respect.

It was with a view of securing this neutral ground as the exclusive basis of their operations, that the founders of the Association cautiously guarded against any extension of its boundaries which might tend to admit new claimants to its occupation. They did not attempt to define the precise limits at which accurate science terminates and speculation begins, but they endeavoured to keep sufficiently within them to prevent the intrusion of discussions which might disturb the peace of our body or even endanger its existence. Experience has fully established the wisdom of this law, and the absolute necessity of a rigid adherence to its provisions.

In returning to the scene of our first labours, the place of our nativity, it becomes us, as grateful children, to acknowledge our filial obligations to our founders.

I regret to say that, for my own part, I can claim no share in the honour which that character confers, having been engaged at the time, in common with my friends the Master of Trinity College and Professor Sedgwick, in duties at Cambridge from which it was impossible for us to escape. I venture, therefore, in the name of all those who are similarly circumstanced with myself, to render our just tribute of gratitude to the venerable Archbishop of this province, who bears the honours of his high station in a green and vigorous old age, and whose munificent patronage and support we must ever be ready to acknowledge; to the Noble Earl, our first President, who maintains so worthily the honours of the house of Wentworth; to Viscount Morpeth, the accomplished representative of the name and honours of another of the princely houses of this great county; to Sir J. Johnstone, who so generously protected the old age of the Father of English Geology; to Sir Thomas Macdougall Brisbane, who is equally eminent as a patron and a cultivator of astronomy, and whose infirm health alone prevents his being present at this Meeting; to Sir David Brewster, so justly celebrated for his numerous and important discoveries in physical optics, and in almost every department of physical science, who first suggested and urged the scheme of our Institution; to Mr. William Vernon Harcourt, our lawgiver and proper founder; to our indefatigable General Secretary, Mr. Murchison, who assisted so materially in our first organization and subsequent progress, and who has only once been absent from our Meetings, when engaged in extending his own Silurian system to the feet of the Ural Mountains and into the steppes of Siberia; to Dr. Daubeny, who has studied so successfully the relations of chemistry to geology and agriculture, and who has at all times laboured so strenuously in our service; to Professor Johnston of Durham, who has taken a distinguished part in the great extension which agricultural chemistry has recently made, and who has at various times been a valuable contributor to our Reports; to Dr. William Pearson, so distinguished as a practical astronomer and the liberal founder of the observatory in this city; to Mr. Greenough, whose map was so important a contribution to English geology; to Professor Forbes of Edinburgh, one of the most distinguished of the living cultivators of physical science, and whose important scientific tours alone have prevented his attendance at some of our later Meetings; to Dr. Scoresby, whose early adventures contrast so remarkably and yet so honourably with the labours and occupations of his maturer years; to Professor Phillips, who has so long and so ably organized the complicated machinery of our Meetings, and reduced our annual volumes into order and form; and to Mr. J. Taylor, our excellent Treasurer, whose punctuality and vigilance has kept order and system in every department of our finances.

A reference to the list of our founders presents, as might be expected after a lapse of thirteen years, some very distinguished names who have been lost to science: in their number we find the name of Mr. William Smith, who first received at our meetings the ample recognition of the value of those original and unaided researches, which must for ever entitle him to be considered as the father of English geology; of Mr. William Allen, of Edinburgh, the eminent mineralogist; of Dr. Lloyd, Provost of Trinity College, Dublin, the father of our excellent colleague, Professor Lloyd, and the founder of that truly illustrious school of accurate science in that university, which has given to the world a Robinson, a Hamilton, and a MacCullagh; of Sir J. Robison, who inherited from his father, the well-known Professor Robison, his taste for science and its application to the arts; of Dr. Henry, one of our most distinguished theoretical and practical chemists, and only second in reputation to his fellow-townsman, Dr. Dalton, whose very recent loss we have occasion to deplore, and whose name, under such circumstances, it would be unbecoming in me to pass over with merely a passing notice.

Mr. Dalton was one of that vigorous race of Cumberland yeomen amongst whom are sometimes found the most simple and primitive habits and manners combined with no inconsiderable literary or scientific attainments. From teaching a school as a boy in his native village of Eaglesfield, near Cockermouth, we find him at a subsequent period similarly engaged at Kendal, where he had the society and assistance of Gough, the blind philosopher, and a man of very remarkable powers, as well as of other persons of congenial tastes with his own. In 1793, when in his twenty-third year, he became Professor of Mathematics and Natural Philosophy in the New College in Mosley Street, Manchester, a situation which he continued to hold for a period of six years, and until that establishment was removed to this city, when he became private teacher of the same subjects, occupying for the purposes of study and instruction the lower rooms of the Literary and Philosophical Society in George Street, rarely quitting the scene of his tranquil and unambitious labours beyond an annual visit to his native mountains, with a joint view to health and meteorological observations.

He made his first appearance as an author in a volume of "Meteorological Observations and Essays," which he published in 1793, a book of humble pretensions and form, but which contains the germ of many of his subsequent speculations and discoveries, more particularly as regards the co-existence of an atmosphere of air and aqueous vapour, and their relations to each other: and his first views of the atomic theory, which must for ever render his name memorable as one of the great founders of chemical philosophy, were first distinctly suggested to him during his examination of olefiant gas and carburetted hydrogen gas. This theory was noticed in lectures which he delivered at Manchester in 1803 and 1804, and much more explicitly in others delivered at Edinburgh and Glasgow in the two following years; it was however first made generally known to the world in Dr. Thomson's Chemistry in 1807, and was briefly but very explicitly developed in his own "System of Chemical Philosophy," the first part of which appeared in the following year; and though his claims to this great generalization were subject to some disputes both at home and abroad, yet in a very short time both the doctrine and its author were acknowledged and recognized by Wollaston, Davy, Berzelius, and nearly all the great chemists in Europe.

It is quite true that many important laws of chemical synthesis had been discovered before his time: Richter, Wenzel and Proust, at various periods between 1777 and 1792, had established the constant proportion in which the elements of many bodies combine, and had likewise hinted at the important derivative law, that if two elements combine in a certain proportion with a third, they may combine in the same proportion with each other. In 1787, Dr. Higgins of Dublin had approximated to the law of the combination of different multiples of the elements of bodies, in the case of sulphur and iron: but these discoveries, considerable as they were, were not generally known, and the laws derivable from them were not formally enunciated; they had hitherto exercised no influence upon the processes or the results of analytical chemistry; and so little was their authority recognized, that even Berthollet, one of the greatest chemists of his age, continued to maintain that the elements of bodies might combine in variable proportions, a conclusion which the vague forms under which the analyses of bodies, more particularly those of the mineral kingdom, were commonly exhibited, was not a little calculated to favour.

The atomic theory, however, by the clear conception which it enables us to form of the conditions of the co-existence of the elements of bodies in chemical combinations, by which they acquire permanent and distinctive characters, as different from the results of their indefinite aggregation and mixture, has totally changed the whole face of the science of chemistry. It was by considering the *weights* as well as the *number* of the elementary atoms which form the compound atom of the resulting body, that this theory was not merely distinguished from the vague speculations of the atomic philosophers of a former age, but became, when it was once admitted and established, the guide as well as the basis of all accurate chemical analysis. The very definite and comprehensive form in which this law was enunciated by its author was the immediate expression of his primary conception of the constitution of bodies; and simple, natural and obvious as it may appear to us who are now familiar with the results to which it leads, it was not, on that account, a less important step in the science of chemistry, whose form and language it rapidly changed: the revolution which it effected in our views of the laws and results of chemical combination, was nearly as great as that which was produced in Physical Astronomy by the discovery and enunciation of the law of universal gravitation.

It has been contended, however, that he only discovers who proves, and that inasmuch as most of the analyses which Dalton made the foundation of his law, were either erroneous or insufficient, he has no sufficient claim to the character of its discoverer. The atomic weight which he assigned to oxygen was 7 instead of 8·01, that of hydrogen being 1; and his analyses of olefiant gas and carburetted hydrogen, which he made, in the first instance, the basis of the law of multiple combining proportions, was likewise imperfect: the theory of atoms also, in the form in which he presented it, was not free from very serious objections, as involving assumptions respecting the ultimate constitution of bodies, which are not only removed beyond the range of our experience, but opposed to our primary conception of matter as susceptible of infinite divisibility. But admitting the defects of his analyses, it may be justly contended that they in no respect affect the form in which he expressed the law of definite proportions; and what is more important, they were not of such a nature as to affect the form and character of the researches, which, even if his fundamental analyses had been found to be perfectly accurate, would still have been necessary for its further and complete development; and what is more, that the bearing of such investigations upon the establishment or refutation of the theory had been fully pointed and exemplified: whilst, in reply to the last objection, it might be contended that not only is our conception, of the infinite divisibility of matter, rather geometrical than physical, but likewise that it by no means precludes other modes of exhibiting the theory in a form in which the use of the term *atom* would be hypothetical only, and not absolute and indispensable.

It is always unsafe and perhaps unphilosophical to speculate upon the amount of the good fortune which is connected with the time and circumstances of any great discovery, with any view to detract from the credit which is due to its author; but it has been contended that Wollaston, Berzelius and others were already in the track which would naturally lead to this important generalization, and that it could not long have eluded the vigilant pursuit of those distinguished chemists. In reply to this insinuation, however, we may venture to repeat, what has been often before observed, that if philosophy be a lottery, those only who deserve to win them, ever draw its prizes; that those only who have scrutinized closely and cautiously the well-known and recognized approaches to the temple of nature, have ever been able to discover the new paths which lead to its unexplored treasures, however plain and obvious, when they are once made known to us, they may appear to be. To Dalton this discovery was not due to any momentary philosophical inspiration, for which his previous contemplations had not prepared his mind; it was the legitimate result of long and profound reflection upon the relations, which chemical analysis had made known to him, of their separate elements to the gaseous, fluid or solid bodies which they composed, and also of the various circumstances which appeared to determine their combination with each other; it was, in fact, the capital conclusion, to which his speculations, from the earliest period of his philosophical life, had constantly been tending.

The atomic theory is not the only great contribution to chemical science which we owe to Dalton; he discovered contemporaneously with Gay-Lussac, with whom many of his researches run parallel, the important general law of the expansion of gases; that for equal increments of temperature all gases expand by the same portion of their bulk, being about three-eighths in proceeding from the temperature of freezing to that of boiling water. His contributions to meteorology were also of the most important kind.

Dr. Dalton was not a man of what are commonly called brilliant talents, but of a singularly clear understanding and plain practical good sense; his approaches to the formation of his theories were slow and deliberate, where every step of his induction was made the object of long-continued and persevering thought; but his convictions were based upon the true principles of inductive philosophy, and when once formed were boldly advanced and steadily maintained: the style of his writings, particularly in his 'System of Chemical Philosophy,' bears strongly the impress of his philosophical character; it is clear, precise, and unembarrassed; always equal to his subject, and never above it.

"Though Dalton's great discovery," says the historian of the inductive sciences, "was soon generally employed and universally spoken of with admiration, it did not bring to him anything but barren praise, and he continued in his humble employment when his fame had filled Europe, and his name become a household word in the laboratory. After some years he was appointed a Corresponding Member of the Institute of France, which may be considered as a European recognition of the importance of what he had done; and in 1826, two medals for the encouragement of science having been placed at the disposal of the Royal Society by the King, one of them was assigned to Dalton for his development of the atomic theory. In 1833, at the meeting of the British Association for the Advancement of Science which was held at Cambridge, it was announced that the King had bestowed upon him a pension of £150*; at the preceding meeting at Oxford, that University

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* This was afterwards increased to £300.

had conferred the degree of Doctor of Laws, a step the more remarkable since he belonged to the sect of Quakers. At all the meetings of the British Association he has been present, and has always been surrounded with the reverence and admiration of all who feel any sympathy with the progress of science. May he long remain among us thus to remind us of the great advance which chemistry owes to him."

This was written in 1837, the year in which an attack of paralysis seriously impaired his powers. He last appeared among us at Manchester, where he received the respectful homage of the distinguished foreigners and others who were there assembled. He died on the 27th of July last, in the 78th year of his age: his funeral, which was public, was attended by all classes of the inhabitants, who felt justly proud of being the fellow-citizen of so distinguished a man.

I now proceed to notice some other topics which are connected with the distribution of the funds, and the general conduct of the affairs of the Association.

Like other public bodies, we have had our periods of financial prosperity and decline, and like other bodies, we have sometimes drawn more freely upon our resources than their permanent prospects would altogether justify; the statement which will be read to you by our excellent Treasurer (see ante, p. xii.), will show that during the last year our capital has been reduced: the great number of life subscribers, which at one time rapidly augmented our resources, has a natural and necessary tendency to reduce our annual subscriptions at every succeeding meeting, and some alterations in the conditions of admission for those inhabitants of the places where we are received, who are not likely to follow the further movements of the Association, have not tended to swell our receipts, though rendered at the time necessary by the great numbers who crowded inconveniently some of our sectional meetings.

I regret to find that some currency has been given to the notion, which I believe to be altogether erroneous and unfounded, that a large excess of income above our necessary expenditure, which may be devoted to the promotion of scientific researches and scientific objects, is essential to the successful working of the business of the Association, and that our movements should therefore be always directed to those places where our coffers are most likely to be filled: it may be quite true that the objects of the Association are most certainly and effectually promoted by going to those places which are likely to attract the largest concourse of scientific visitors, and that our financial thus becomes immediately dependent upon our general prosperity; but if under any circumstances these two principles of selection should ever come into collision with each other, there can be no doubt to which of them our preference should be given; and though I think we should very imperfectly accomplish the design of our institution, if our tour of visits did not comprehend in their turn every important district in the three kingdoms, yet it would be not only unadvisable, but dangerous even to our very existence, if we fixed our standard in any locality which did not present a reasonable prospect of procuring the requisite scientific supplies, and of not sustaining the union as well as vigorous action of the body to which we belong.

There are some great principles which have generally governed the Committee of Recommendations in recommending, and the General Committee in confirming, grants of money for scientific objects, which I hope we shall never lose sight of,—that no part of our funds should ever be applied to defray the personal expenses or to compensate the loss of time or labour of any of our members in making researches or experiments, even when they are undertaken or made at the request of the Association; that they should not be granted for the general promotion of this or that branch of science, but for specific and well-defined objects; that in no case should they be applied to make a bookselling or other speculation remunerative, which would otherwise not be so; that the results of inquiries which are carried on partly or wholly at our charge, should so far belong to the Association as to secure its just claim to the scientific credit which they are calculated to confer. I know that some of these principles have been in some instances partially departed from, under very pressing and peculiar circumstances; but the remembrance of the discussions to which some claims of this nature have given rise, which it was improper to grant, but difficult and painful to refuse, has tended to confirm my own impression not merely of the wisdom of those important rules, but likewise of the almost imperative necessity of adhering to them.

It was at the memorable meeting of the Association at Newcastle, a period of great financial prosperity, that it was resolved to recommend and to undertake a very extensive system of astronomical reductions and catalogues: the first was the republication, under a greatly extended and much more complete form, of the Astronomical Society's Catalogue, exhibiting the latest and most accurate results of astronomical observations, reduced to a common epoch, with the permanent coefficients for their reduction which the Nautical Almanac does not supply. The second was the reduction of all the stars in the 'Histoire Céleste' of Lalande, nearly 47,000 in number, containing the most complete record which existed sixty years ago of the results of observation, and affording therefore an interval of time so considerable as to enable astronomers, by comparing them with their positions as assigned by modern observations, to determine their proper motions and other minute changes, almost independently of the errors of observation: a third was a similar reduction of the stars in the 'Cœlum Stelliferum Australe' of Lalande, 8700 in number, which had assumed an unusual degree of importance from the recently completed survey of the southern hemisphere by Sir John Herschel, and the establishment of observatories at Paramatta and the Cape.

Another work of still greater expense and labour, was the reduction and publication of the Planetary and Lunar Observations at Greenwich, from the time of Bradley downwards, which was undertaken by the Government at the earnest application of a Committee of the Association, appointed for that purpose and acting in conjunction with the Council of the Royal Society: this great undertaking has been nearly brought to a conclusion under the systematic and vigilant superintendence of the Astronomer Royal.

The publication of these works must form a great epoch in astronomy; and though the expense to which it has exposed the Association has been very considerable, and will amount when completed to nearly £3000, yet it cannot fail to prove a durable monument of the salutary influence which it has exercised upon the progress of science. The catalogues of Lacaille and Lalande are to be printed and published, as is already known to you, at the expense of Her Majesty's Government, and the first, which has been prepared under the superintendence of Professor Henderson, is nearly complete: the catalogue of Lalande and the British Association Catalogue were placed under the superintendence of Mr. Francis Baily, and in referring to the irreparable loss which astronomical science has so recently sustained by his death, I should neither do justice to my own feelings nor to his long and important connection with the Association if I did not detain you for a few moments.

Mr. Baily was undoubtedly one of the most remarkable men of his time; it was only in 1825 that he retired from the Stock Exchange with an ample fortune, and with a high character for integrity and liberality; but his subsequent career almost entirely belongs to astronomy, and is one of almost unexampled activity and usefulness. The Astronomical Society was almost entirely organized by him, and throughout life he was the most considerable contributor to its Memoirs; the catalogue of the Astronomical Society, the funds for which were contributed by several of its members, was entirely formed under his superintendence, and we are chiefly indebted to his exertions for the more ample development which the Nautical Almanac has of late years received, and which has added so much to its usefulness. There was no experimental research connected with the more accurate determinations of astronomy or physical science, undertaken in this country, which was not generally entrusted to his care.

The discovery, or rather notice, by Bessel of the correction due to the resistance of the air, which had been neglected in the reduction of the experiments for the determination of the length of the pendulum by Kater, and which consequently vitiated the correctness of the definition of the standard of length which had been prematurely adopted by the legislature, first directed his attention, not merely to the character and influence of this correction* as affected by the forms of the pendulums which were used, but likewise to the modes which had been adopted for suspending them; and the discussion of the elaborate series of experiments which he instituted for this purpose, which was given in the Philosophical Transactions for 1829, is a model of that happy union of precise and luminous theoretical views with the utmost minuteness of practical details, for which his memoirs are generally so remarkable. The reduction and discussion of the pendulum observations made by Captain Foster, in his well-known voyage in the Chanticleer, to which that experimental inquiry had been preliminary, were entrusted to him by the Admiralty, after the unfortunate death of that valuable officer, and were published in the seventh volume of the Memoirs of the Astronomical Society, forming a contribution to this branch of science which was only second in importance, whether we regard the character of the observations themselves or of the conclusions to which they were subservient, to those which recorded the observations which had been previously made by Colonel Sabine in his various scientific voyages.

His comparison of the Standard Scale of the Astronomical Society with the Parliamentary Standard and its various representatives, as well as with the French mètre, presents another remarkable example of his unequalled accuracy and care in conducting experimental inquiries of the most delicate and difficult nature, and the result of them has acquired an additional value and importance, from the destruction of our national standards in the burning of the Houses of Parliament. He had also undertaken, for the Commission of Weights and Measures, the conduct of the process for forming the new Standard Yard from the scale which he had thus constructed, but unfortunately little progress had been made in the execution of this task, for which his habits so peculiarly fitted him, when death put an end to his labours.

It was in consequence of a suggestion of Mr. De Morgan that he undertook, at the expense of the Government, the repetition of the celebrated experiment of Mr. Cavendish, and his account of the various precautions which he considered necessary to obviate every source of uncertainty and error, and to overcome the practical difficulties which presented themselves in the course of the inquiry, as well as his theoretical discussion of the conclusions to which

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* This correction had been previously determined by Colonel Sabine, by swinging a pendulum in air and in vacuo.

they lead, which forms a recent volume of the Memoirs of the Astronomical Society, will be a durable monument to his patience, perseverance and skill.

He published, at the request of the Admiralty, the Correspondence and Catalogue of Flamsteed, with a most laborious examination and verification of all his authorities. He presented to the Astronomical Society a volume containing the catalogues of Ptolemy, Ulugh Beigh, Tycho Brahe, and Hevelius and Halley, with learned prefaces and critical notes, showing their relations to each other, and to later catalogues. His preface and introduction to the British Association Catalogue, and more than one third of the catalogue itself, are already printed, and from the critical examination of the authorities upon which his assumed positions rest, and the careful distribution of the stars which are selected, (more than 8000 in number) in those parts of the heavens where they are likely to be most useful to observers as points of comparison, it promises to be the most important contribution to the science of practical astronomy which has been made in later times. The whole of the stars of the 'Histoire Céleste' are reduced and a considerable portion (more than one-fifth) printed, but it is not known whether the introductory matter, which from him would have been so valuable, was prepared at the time of his death.

Mr. Baily was the author of the best Treatise on Life Annuities and Insurances which has yet appeared, as well as of several other publications on the same subject; his knowledge of the mathematicians of the English School was very sound and complete, though he had never mastered the more refined resources of modern analysis. His conception of mechanical principles and of their bearing upon his experimental researches, was singularly clear and definite, and though in the prosecution of the Cavendish and other experiments, he freely availed himself of the assistance of the Astronomer Royal and of Mr. De Morgan, in the investigation of formulæ, which required the aid of dynamical or other principles which were somewhat beyond the reach of the mathematics of the school with which he was familiar, yet he always applied them in a manner which showed that he thoroughly understood their principle, and was fully able to incorporate them with his own researches.

In the midst of these various labours (and the list which I have given of them, ample as it is, comprehends but a small part of their number), Mr. Baily never seemed to be particularly busy or occupied; he entered freely into society, entertaining his scientific as well as his mercantile friends at his own house with great hospitality. He was rarely absent from the numerous scientific meetings of Committees and Councils (and he was a member of all of them), which usually absorb so large a portion of the disposable leisure of men of science in London; but if a work or inquiry was referred to him, it was generally completed in a time which would have been hardly sufficient for other men to make the preliminary investigations. Much of this was undoubtedly owing to his admirable habits of system and order; to his always doing one thing at one time; to his clear and precise estimate of the extent of his own powers. Though he always wrote clearly and well, he never wrote ambitiously; and though he almost always accomplished what he undertook, he never affected to execute, or to appear to execute, what was beyond his powers. This was the true secret of his great success, and of his wonderful fertility, and it would be difficult to refer to a more instructive example of what may be effected by practical good sense, systematic order, and steady perseverance.

It was the same Meeting at Newcastle which gave rise to the design for the greatest combined scientific operation in which the Association has ever been engaged, for the extension of our knowledge of the laws of magnetism and meteorology.

It was the publication of Colonel Sabine's 'Report on the Variations of the Magnetic Intensity at different points of the Earth's Surface,' and the maps which accompanied it, which appeared in our volume for 1837, which first enabled the celebrated Gauss to assign provisionally the coefficients of his series for expressing the magnetic elements: the proper data of this theory are the values of the magnetic elements at given points uniformly and systematically distributed over the surface of the earth, and it was for the purpose of supplying the acknowledged deficiency of these data and of determining the laws which regulated the movements of this most subtle and mysterious element, which induced the Association to appoint a Committee to apply, in conjunction with the Royal Society, to Her Majesty's Government to make a magnetical survey of the highest accessible latitudes of the Antarctic seas, and to institute fixed magnetical and meteorological observatories at St. Helena, the Cape, Hobarton, and Toronto, in conjunction with a normal establishment at Greenwich, and in connection with a great number of others on the continent of Europe, where systematic and simultaneous observations could be made, which would embrace not only the phænomena of magnetism, but those of meteorology also. It is not necessary to add that the application was promptly acceded to. The views and labours of the framers of this magnificent scientific operation, the brilliant prospects of discovery which it opened, the noble spirit of cooperation which it evoked in every part of the civilized world, were alluded to in terms so eloquent and so just in the opening address of Mr. William Vernon Harcourt, when occupying this Chair at Birmingham, that I should do little justice to them if I employed any terms but his own, and I must content myself with simply referring to them. Much of what was then anticipated has been accomplished, much is still in progress, and much remains to be done; but the results which have already been obtained have more than justified our most sanguine expectations.

Sir James Ross has returned without the loss of a man, without a seaman on the sick list, after passing three summers in the Antarctic seas, and after making a series of geographical discoveries of the most interesting and important nature, and proving in the language of the Address to which I have just referred, "that for a man whose mind embraces the high views of the philosopher with the intrepidity of the sailor, no danger, no difficulty, no inconvenience could damp his ardour or arrest his progress, even in those regions where

"Stern famine guards the solitary coast,
And winter barricades the realms of frost."

The scientific results of the two first years of this remarkable voyage have been discussed and published by Colonel Sabine in his 'Contributions to Terrestrial Magnetism,' in the Transactions of the Royal Society, and they are neither few nor unimportant. They have shown that observations of the declination, dip and intensity, the three magnetic elements, may be made at sea with as much accuracy as on land, and that they present fewer anomalies from local and disturbing causes; that the effects of the ship's iron are entirely due to induced magnetism, including two species of it, one instantaneous, coincident with and superadded to the earth's magnetism, and the other a polarity retained for a shorter or longer period, and transferable therefore during its operation by the ship's motion from one point of space to another; that in both cases they may be completely eliminated by the observations and formulæ which mathematicians have proposed for that purpose. No intensity greater than 2·1 was observed; and the magnetic lines of equal declination, dip and intensity, were found to differ greatly from those laid down in Gauss's theoretical map, the northern and southern hemispheres possessing much greater resemblance to each other than was indicated by that primary and necessarily imperfect essay of the theory.

The range of Sir James Ross's observations extends over more than three-fourths of the navigable parts of the southern seas, and you will learn with pleasure that one of his most efficient officers, Lieut. Moore, has been despatched from the Cape with a vessel under his command to complete the survey of the remainder.

Nothing could exhibit in a more striking light the completeness of the organization and discipline of the system of magnetic observatories than the observations of the great magnetic storm of the 25th of September 1841; it was an event for which no preparation could be made, and which no existing theory could predict; yet so vigilant and unremitting was the watch which was kept, that we find it observed through nearly its whole extent, and its leading circumstances recorded at Greenwich, in many of the observatories on the continent of Europe, at Toronto, St. Helena, the Cape, Hobarton, and at Trevandrum in Travancore; for even the mediatized princes of the East have established observatories as not an unbecoming appendage to the splendour of their courts. Some of the observations of this remarkable phænomenon, and of many others (twenty-seven in number) of a similar nature, have been discussed with great care and detail by Colonel Sabine, and lead to very remarkable conclusions. They are not absolutely simultaneous at distant stations, nor do they present even the same succession of phases as at first anticipated; and it is the disturbances of the higher order only which can be considered as universal. They are modified by season as well as by place; the influence of winter in one hemisphere and of summer in the other, on the same storm, being clearly distinguishable from each other. The simultaneous movements in Europe and America have been observed to take place sometimes in opposite and sometimes in the same direction, as if the disturbing cause was in one case situated between these continents, and in the other not; and we may reasonably expect, when our observatories are furnished with magnetometers of sufficient sensibility to indicate instantaneously the effects of disturbing causes, that the localities in which they originate may be approximately determined. These are very remarkable conclusions, and well calculated to show the advantages of combined observations. In such inquiries, observations in a single and independent locality, however carefully they may be made, are absolutely valueless.

The meteorological observations are made, in all these observatories, on the same system and with equal care with those of magnetism; they embrace the mean quantities, diurnal and annual variations, of the temperature, of the pressure of the atmosphere, of the tension of the aqueous vapour, of the direction and force of the wind, with every extraordinary departure from the normal condition of these elements, as well as of auroral and other phænomena. It would be premature to speak of the conclusions which are likely to be deduced from these observations, inasmuch as the reduction and comparison of them, with the exception of those at Toronto and Greenwich, has hitherto made little progress; but they cannot fail to be highly important; for it is by the comparison of observations such as these, made with reference to a definite system, with instruments constructed upon a common principle and carefully compared with each other, and by such means alone, that the science of meteorology can be not only advanced but founded.

Our philosophical records have for the last century been deluged with meteorological observations; but they have been made with instruments adapted to no common principle, compared with no common standard, having reference to no station but their own, and even with respect to it possessing no sufficient continuity and system; they have been for the most part desultory, independent, and consequently worthless. It would be unjust however to the merits of one of the most assiduous and useful of our members, Mr. Snow Harris, if I did not call your attention, in connection with this subject, to his Reports (included in the Reports of our Twelfth Meeting) on the meteorological observations at Plymouth made by him, or under his superintendence with the aid of a very moderate expenditure of the funds of the Association. They comprehend observations of the thermometer at every hour of the day and night during ten years, and of the barometer and anemometer during five years, carefully reduced and tabulated, and their mean results *cymographed* or projected in curves. Nothing can exceed the clearness with which the march of the diurnal changes are exhibited in these results, and I sincerely hope that means may be found for printing them in such a form as may secure to them their permanent authority and value.

Another discussion of the meteorological observations made at sixty-nine stations, at the equinoxes and solstices, in the years 1835, 1836, 1837 and 1838, which have been reduced and cymographed with great care by Mr. Birt, at the expense of the Association, forms the subject of a Report by Sir John Herschel in the volume of our Reports for the present year, and may be considered as a prelude, on a small scale, of the species of analysis which the results of the great system of observations now in progress should hereafter undergo. The inferences which are drawn from the examination of the changes of atmospheric pressure, with more especial reference to the European group of stations only, are in the highest degree instructive and valuable.

The system of magnetic observatories was at first designed to continue for three years only, but was subsequently extended to the 1st of January 1846; for it was found that the first triennial period had almost elapsed before the instruments were prepared or the observers instructed in their duties or conveyed to their stations; the extent also of cooperation increased beyond all previous expectation. Six observatories were established, under the zealous direction of M. Kupffer, in different parts of the vast empire of Russia, the only country, let me add, which has established a permanent physical observatory. The American government instituted three others, at Boston, Philadelphia and Washington; two were established by the East India Company, at Simla and Sincapore; from every part of Europe, and even from Algiers, offers of cooperation were made. But will the work which has thus been undertaken with such vast prospects be accomplished before the termination of the second triennial period? or is it not probable that the very discussion of the observations will suggest new topics of inquiry or more delicate methods of observation? If the march of the diurnal, monthly and annual movements of the needle be sufficiently determined, will its secular movements be equally well known? in other words, shall we have laid the foundation of a theory, which may even imperfectly approximate to the theory of gravitation in the accuracy and universality of its predictions? It is with reference to these important questions, and the expediency of continuing the observatories for another triennial term, that M. Kupffer has addressed a letter to Colonel Sabine, suggesting the propriety of summoning a magnetic congress, to be held at the next Meeting of the British Association, and at which himself, Gauss, Humboldt, Plana, Hansteen, Arago, Lamont, Kreil, Bache, Quetelet, and all other persons who had taken a leading part in conducting, organizing, or forwarding these observations should be invited to attend.

This proposal has been for some time under the anxious consideration ot your Committee of Magnetism, consisting of Sir John Herschel, Colonel Sabine, the Astronomer Royal, Dr. Lloyd, the Master of Trinity College, and myself; and it will be for the General Committee, before we separate, to decide upon the answer which must be given. I think I may venture to say that there would be but one feeling of pride and satisfaction at seeing amongst us the whole or any considerable number of these celebrated men; and there can be little doubt but that whatever be the place at which you may agree to hold your next Meeting, they will experience a reception befitting the dignity of these great representatives of the scientific world.

It is quite true that the preparations for such a meeting would impose upon your Committee of Magnetism, and more especially upon Colonel Sabine, no small degree of labour. Reports must be received from all the stations, up to the latest period, of the state of the observations; their most prominent results must be analysed and compared, and communicated as extensively as possible amongst the different members of the Congress, so as to put them in possession of the facts upon which their decision should be founded. Great as is our reliance upon the activity and zeal of Colonel Sabine and of his admirable coadjutor, Lieut. Riddell, perfect as is his acquaintance with every step of an inquiry with the organization and conduct of which he and Prof. Lloyd have had the principal share, I fear that he would require greater means than his present establishment could furnish, to meet the pressure of such overwhelming duties.

But if it should be the opinion of such a congress, that it was expedient to continue the observations for another triennial period, and if such an opinion was accompanied by an exposition of the grounds upon which it was founded, there can be little doubt that there is not a government in the civilized world which would not readily acquiesce in a recommendation which was supported by such authority.

The last volume of our Transactions is rich in reports on natural science, and more especially in those departments of it which have an important bearing on geology; such is Prof. E. Forbes's Report "On the Distribution of the Mollusca and Radiata of the Ægean Sea," with particular reference to the successive zones of depth which are characterized by distinctive forms of animal life, and the relation existing between living and extinct species. You will, I am sure, be rejoiced to hear that Her Majesty's Government have not only secured the services of its author in connection with the Geological Survey, but have most liberally undertaken, upon the application of the Council, to defray the expense of printing the very interesting work upon which this Report is founded. The Report of Mr. Thompson, of Belfast, on an analogous branch of the Fauna of Ireland, is remarkable for the minuteness and fullness of the information which it conveys. Prof. Owen has continued his Report "On the British Fossil Mammalia," which was begun in the preceding volume, and towards procuring materials for which a contribution was made from the funds of the Association. I regret to find that a class of reports on the recent progress and existing state of different branches of science, which occupied so large a portion of our earlier volumes, and which conferred upon them so great a value, have been almost entirely discontinued. If the authors of these Reports could find leisure to add to them an appendix, containing the history of the advances made in those branches of science during the last decad of years, they would confer an important benefit on all persons engaged in scientific inquiries.

The history of the sciences must ever require these periodical revisions of their state and progress, if men continue to press forward in the true spirit of philosophy, to advance the boundaries of knowledge; for though there may be impassable boundaries of human knowledge, there is only one great and all-wise Being, with whom all knowledge is perfect, who can say, "Thus far shalt thou go and no further." The indolent speculator on the history of the sciences may indulge in an expression of regret that the true system of the universe is already known, that the law of gravitation is discovered, that the problem of the three bodies is solved, and that the mine of discovery is exhausted and that there remain no rich masses of ore in its veins to make the fortune and fame of those who find them; but it is in the midst of this dream of hopelessness and despondency that he is startled from time to time by the report of some great discovery—a Davy has decomposed the alkalies, a Dalton has discovered, and a Berzelius has completely developed, the law of definite proportions; a Herschel has extended the law of gravitation to the remotest discoverable bodies of the universe, and a Gauss has brought the complicated and embarrassing phænomena of terrestrial magnetism under the dominion of analysis; and so it will ever continue to be whilst knowledge advances, the highest generalizations of one age becoming the elementary truths of the next. But whilst we are taking a part in this great march of science and civilization, whilst we are endeavouring to augment the great mass of intellectual wealth which is accumulating around us, splendid as may be the triumphs of science or art which we are achieving, let us never presume to think that we are either exhausting the riches or approaching the term of those treasures which are behind; still less let us imagine that the feeble efforts of our philosophy will ever tend to modify the most trivial and insignificant,—if aught can be termed trivial and insignificant which He has sanctioned,—of those arrangements which the great Author of Nature has appointed for the moral or material government of the universe. Far different are the lessons which he taught us by the revelation of his will, whether expressed in his word or impressed on his works; it is in a humble and reverent spirit that we should approach the fountain of all knowledge, and it is in a humble and reverent spirit that we should seek to drink of the living waters which for ever flow from it.

Report of the Council to the General Committee.

1. The General Committee assembled at Cork in August 1843 having passed a Resolution to the effect that an application should be made, on the part of the British Association, to the Master-General of the Ordnance, entreating his assistance in the proposed experiments with Captive Balloons, the Council has to report that the application has been accordingly made, and that a reply has been received from the Master-General, stating that the Commandant of the Garrison at Woolwich has been directed to afford the facilities and assistance which are requested.

2. The General Committee assembled at Cork having directed that "an application be made to Her Majesty's Government for the insertion of Contour Lines of Elevation on the Ordnance Maps of Ireland, such lines being of great value for engineering, mining, geological and mechanical purposes,"—the Council has to report, that a copy of this Resolution was transmitted to Her Majesty's Government, accompanied by the following Memorial:—

"The undersigned Members of the British Association for the Advancement of Science have the honour, by the direction of the General Committee of the Association, assembled at Cork in August 1843, to make an earnest application to Her Majesty's Government for the addition to the engraved sheets of the Ordnance Survey of Ireland, of a series of *contour lines*, representing the various degrees of elevation of the surface of the country from actual survey.

"The grounds of this application are, that the execution of such lines would prove eminently serviceable to the landed, commercial, and mining interests of Ireland; that it would afford information and assistance of the highest value to persons engaged in the cultivation of science, and in applying scientific discoveries to practical purposes; and that the work sought to be accomplished can be performed by the present Ordnance establishment in Ireland within a short time and at a moderate cost.

"In all cases where the improvement of farms, by opening them to markets, or to each other, by the cheapest roads, by drainage or by irrigation, is desired—in all the operations for ameliorating the condition of towns, especially by diverting for their use existing streams of water, or obtaining new supplies by Artesian wells—in arranging the situations of coal-pits and mining adits—in planning or diverting roads, railways and canals, a knowledge of the inequalities of level of the surface of the country is of primary importance.

"This knowledge, *contour lines*, engraved on the Ordnance Maps, would supply, not only in a general sense, but with an exactness suited to particular cases and actual operations, and thereby facilitate in a high degree the preparation of good plans for public improvement, and save the heavy expense of innumerable special surveys, which, however well performed, cannot be compared in authenticity and applicability with the results of a general system, which, once completed, would be available for new cases and future times.

"Independent of the assistance which the Ordnance Maps thus rendered complete would afford to public works and private enterprises, their augmented value in a multitude of cases, embracing the applications of science and the ordinary concerns of life, is worthy of attention. In fact, without the introduction of such lines marking inequalities of level, these splendid maps would be incomplete, and less useful to the public than they might be made.

"The British Association has been assured that this desirable addition to the Irish maps is extremely practicable at the present time, because in the progress of the survey a great number of the lines and stations necessary for contouring have been determined, and a large body of persons has been trained to the correct use of the instruments which must be employed in the process, whose services are now disposable. As experiments, the county of Kilkenny, and parts of Donegal and Louth, have been already contoured for general purposes; a property of the Crown at Llangeinor, in South Wales, for mining operations, and Windsor for sanatory objects.

"From these trials the probable cost of the operations, by which the data for contouring the whole of the Maps will be supplied, has been estimated at £10,000, a sum which it is hoped Her Majesty's Government will deem altogether inconsiderable in comparison with the public advantages which cannot fail to arise from the performance of the work. It is also worthy of notice, that the newly-discovered process of electrotype is applicable to the purpose of enabling duplicate plates to be produced at an extremely small cost, in which these lines can be inserted, leaving the original plate unaltered, to furnish other duplicates for other purposes—such, for example, as the insertion of geological lines.

"The British Association therefore begs leave to solicit from Her Majesty's Government a favourable consideration of the subject; and that Her Majesty's

Government will be pleased to authorise the officers of the Ordnance department to take immediate steps for contouring on the whole of the maps of Ireland, according to the specimen already executed for the county of Kilkenny."

(Signed by the Earl of Rosse, President; the Marquis of Northampton and John Taylor, Esq., Members of the Committee.)

No direct reply has been received to this application; but the Council has learnt from other sources that the Contour Lines are to be inserted in the Ordnance Maps.

3. The General Committee assembled at Cork having passed a Resolution to the effect that application be made to Her Majesty's Government to give its aid in the publication of Professor Edward Forbes's researches in the Ægean Sea, the Council has to report that the General Secretaries, accompanied by Mr. Lyell, waited on Sir George Clerk, one of the Secretaries of the Treasury, and presented a Copy of the Resolution passed by the General Committee, accompanied by the following Memorial:—

"Professor E. Forbes was engaged as naturalist in the 'Beacon' surveying-vessel, under the command of Captain Graves, employed in a Hydrographical Survey of the Mediterranean, by direction of the British Government. While thus engaged, he embraced every occasion of obtaining, by the dredge, exact knowledge of the contents of the Ægean Sea, at all depths, ranging from the surface to 230 fathoms: he studied the fauna and flora of the isles of the Archipelago and the mountains of Lycia, and, by careful and copious notes and drawings, he has preserved authentic and complete accounts of the information thus gathered.

"During the survey of the submarine zoology of the Ægean, and in the examination of the coasts and interior country, Professor Forbes observed upwards of 150 species of animals which he regards as altogether new to science, and a much larger number which have been previously unknown in these localities.

"Among many interesting results established by careful registration of the circumstances under which the several races of plants and animals were discovered in the Ægean, it appears that several distinct zones of depth are naturally defined in the Ægean Sea, by distinct and peculiar groups of plants and animals; that the lower we pass downward in this sea the more do the organic forms resemble species which occur near the surface of the ocean in arctic regions; and that some species of Mollusca have been dredged *alive* in the Ægean of which the remains only had been previously known in a *fossil state*, and were thought to be *extinct*.

"These and some other conclusions derived by Professor Forbes from his researches, have an important bearing on the philosophy of natural history, and on the establishment of general truths in geology. The announcement of them in a report to the British Association has created great interest among persons devoted to natural science; and it appears desirable for the advancement of knowledge that the *data* on which the conclusions rest should be published in a complete form. This cannot be done upon the expectation of remuneration through the ordinary channels of trade; nor is it compatible with the means or the course of proceeding of the Association to undertake such a publication, though the sum of £100 was willingly devoted from their funds to assist Professor Forbes in defraying the cost of the dredging operations, whose results are esteemed to be so valuable: except by aid from the Government, the results of Professor Forbes's labours can never be fully given to the public. If published in detached fragments and at various times, they will be almost inaccessible, except to a very small number of students; whereas, published by Government, the whole may be produced in a complete and creditable form, and be placed within the reach of the public at a moderate price, and given to foreign institutions of science, from which returns of like nature may be expected.

"To fulfil these conditions, to render the publication possible, and to make it useful by a sufficient series of illustrations, would probably require a sum not exceeding £500."

The Council has now the pleasure of stating, that Sir Robert Peel has consented to Mr. Forbes's work being published at the expense of Her Majesty's Government, under the superintendence of the Comptroller-General of Stationery, and agreeably to the plan submitted by the General Secretaries, viz. that the publication should consist of about 300 pages of text in octavo, and about 100 plates; 500 copies to be printed of the text, and the plates to be taken off as required; that 50 copies should be presented in the name of the British Government to public libraries and institutions at home and abroad, according to a list to be furnished; that 50 copies should be at the disposal of Mr. Forbes, to be presented to persons who had assisted in his researches, or contributed towards the work; and that the remainder of the copies should be sold at a price considerably less than that of their cost.

4. The Council reports that the General Treasurer has received from Her Majesty's Treasury the sum of £1000, granted by Government for the publication of the Catalogue of Stars in the 'Histoire Céleste' of Lalande, and of Lacaille's 'Catalogue of Stars in the Southern Hemisphere.'

5. The Council reports that the railway geological sections and documents connected therewith, which had been made at the expense of the British Association at a cost of £363 6*s.* 9*d.*, have been transferred to the Museum of Œconomic Geology, upon the assurance that these sections and documents shall be open to the public, as other documents in the Mining Record Office at the Museum now are, and with the understanding that the sections are to be continued by the authority and at the expense of Government, for which purpose a sum of £250 has been taken on the estimates of the Museum of Œconomic Geology for 1844—45.

6. The Council has added the name of Dr. Langberg, of Christiania, to the list of Corresponding Members of the British Association.

7. The Council has requested Professor Wheatstone to prepare a Report on the performance of the Self-registering Meteorological Apparatus belonging to the Observatory at Kew, and to present it at the Meeting at York.

8. The Council has requested Messrs. Wheatstone and Ronalds to prepare a Report on the performance of the Electrical Apparatus established at Kew, and on the results obtained with it; to be presented at the Meeting at York.

9. The Council, having ascertained that the Earl of Rosse, President of the Association, would not be indisposed to communicate to the Meeting at York an account of the recent improvements which he has effected in the construction of Reflecting Telescopes, has requested His Lordship to prepare a Report on that subject; to be presented at the York Meeting.

10. It having been stated to the Council that since the electrical apparatus has been fitted up in the cupola of the Kew Observatory, Mr. Galloway has been required, in addition to the general duties for which he was engaged, to attend to its registry every day from half an hour before sunrise until night; and that the same constant attendance would continue to be required of him for this and other meteorological registries, the Council has increased Mr. Galloway's salary to One Guinea a week, on the understanding that for this salary his whole time should be at the service of the Association.

11. The General Committee assembled at Cork having placed at the disposal of the Council a sum of £200 for the purpose of maintaining the establishment at Kew, the Council reports that of this sum £118 *5s.* $2\frac{1}{2}$*d.* has been expended in the year which now closes, for salary and house-expenses.

12. Letters have been received from the Mayor and Town Council of the city of Bath; from the Chairman, Committee and Secretary of the Bath Royal Literary and Scientific Institution; and from the President and Vice-Presidents of the Bath Mechanics' Institution—inviting the British Association to hold its meeting in the year 1845 in that city.

13. The Council has been informed that the Senate of the University of Cambridge has passed a grace to the effect that if the meeting of the British Association should take place at Cambridge in 1845, the use of the Senate-house, and such of the public buildings and lecture-rooms as may be required for the different general and sectional meetings of the Association, should be granted under the superintendence of a syndicate; and further, that the Philosophical Society of Cambridge designs, at the York Meeting, to invite the British Association to hold their Meeting in 1845 at Cambridge.

14. A letter has been received from Charles P. Deacon, Esq., Town Clerk of Southampton, containing an invitation from the Mayor and Borough Council to the British Association, to hold its Meeting for 1845 at Southampton; and stating that in such case the Guildhall, Audit-house, and other public buildings, should be placed at the disposal of the Association; and that the Literary and Scientific Society and the Polytechnic Institution would also place their lecture and other rooms at the disposal of the Association, and most cheerfully co-operate with the authorities in affording every facility and assistance in their power.

(Signed on the part of the Council) ROSSE.

York, September 25th, 1844.

REPORTS

ON

THE STATE OF SCIENCE.

On the Microscopic Structure of Shells. *By* W. Carpenter, *M.D., F.R.S.*

I. *Introductory Remarks.*

I have in vain searched the works of recent Conchological writers, for any indication that Shell has any claim to the title of an *organic structure.* The researches of Reaumur and Hatchett appear to have induced the universal belief, that shell is an *inorganic* exudation from the surface of the mantle, consisting of calcareous particles held together by a sort of animal glue. It seems to have been formerly maintained by Herissant, however, that shell has an organic structure, and that it grows by interstitial deposit in the manner of bone. I have not been able, however, to find his original paper; and only make this statement on the authority of a reference which I have found to it in the article *Conchyliologie* in the 'Encyclopédie Méthodique,' in which he is quoted as having endeavoured (but failed) to establish by "les expériences ingénieuses, bien plus que solides," that shells grow by intus-susception, instead of by accretion, as demonstrated by Reaumur. In this doctrine he was undoubtedly wrong, as I shall hereafter show; since, although all shell possesses a more or less definite organic structure, this structure rather corresponds with that of the various Epidermic appendages of Vertebrated animals, than with that of their internal vascular skeleton; and its mode of growth must therefore be analogous rather to that of the former than to that of the latter.

The idea that such would be probably found to be the case, I expressed in the second edition of my 'Principles of General and Comparative Physiology' (October 1841), as follows:—"The dense calcareous shells of the Mollusca, and the thinner jointed envelopes of the Crustacea, have been commonly regarded as mere exudations of stony matter, mixed with an animal glue secreted from the membrane which answers to the true skin. The hard axes and sheaths of the Polypifera, however, have been also regarded in the same light; and yet, as will hereafter appear, these are unquestionably formed by the consolidation of what was once living tissue*. From the analogy which the shells of Mollusca and Crustacea bear to the epidermic appendages of higher animals, there would seem reason to believe that the former, like the latter, have their origin in cells, and that these are afterwards hardened by the deposition of earthy matter in their interior."—(§ 44.)

Acting upon this view, I commenced, in the spring of 1842, a series of in-

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* Reference was here made to the researches of M. Milne-Edwards, upon the development and growth of some of the corals. The nature of their organic structure has been subsequently elucidated with great success by Mr. Bowerbank.—(Phil. Trans. 1842.)

quiries into the structure of the shells of Mollusca, Crustacea, and Echinodermata; which I have since been prosecuting as time and opportunity have been afforded me. About the same period, Mr. Bowerbank commenced an independent series of observations; which have had reference, however, rather to the *formation* of shell, than to its microscopic characters when complete; and which have been limited to a comparatively small number of species, whilst my own have included a very extensive range. Finding that our paths of inquiry were so distinct, Mr. Bowerbank and I agreed to pursue them independently of each other; and the results of our researches were simultaneously communicated,—on his part to the Microscopical Society,—and on mine to the Royal Society,—in January 1843. A brief sketch of my own inquiries was laid before the British Association at its Cork meeting; and, with the aid of the grant which was then made to me from the funds of the Association, together with the assistance I have received from various quarters, in regard to the collection of subjects for examination,—especially from the Geological Society, the Council of which has liberally permitted me to examine duplicate specimens from its valuable museum, and from Messrs. H. Cuming, S. Worsley, S. P. Pratt and J. Morris,—I have made during the past year little short of *a thousand* preparations of shell-structure. A considerable part of my labour has been directed to the determination of the questions,—whether an uniform structure prevails through every part of the same shell, so that the structure of the whole shell may be predicated from that of a small portion of it,—and whether the same structure is found in different individuals of the same species, and among different species of the same genus. It is obvious that a settlement of these questions must be of great importance in the application of the Microscope to the determination of fossil shells; and I think that I am now entitled to answer them with some degree of confidence. I have, in a considerable number of instances, submitted *every portion* of a shell to microscopic investigation, selecting such specimens as, from the peculiar characters of their structure, would serve as types to which to refer others; and I have invariably found that an uniform structure pervades the whole of each; so that the examination of but a very small fragment is sufficient to determine the structure of the entire shell. I feel equally certain with respect to the correspondence between the structure of different individuals of the same species; as I have never found any decided variation, although I have in some instances examined several specimens of one kind. With respect to the degree of difference which may exist among the several species of the same genus, I am not yet prepared to speak with certainty. In general I have found the correspondence such, that the *size* of the elementary parts is the chief point of difference; but occasionally I have found particular forms of structure present in one species and absent in another. It will hereafter appear, however, that this difference corresponds with other variations, which are probably to be considered as establishing generic distinctions in the cases in question.

In the following Report, it is my intention to give a general account of the chief forms of elementary structure, which I have met with in Shell; and to enter into systematic details in regard to the group of *Brachiopoda*, and the families of *Placunidæ*, *Ostraceæ*, *Pectinidæ*, *Margaritaceæ*, and *Unionidæ*, among the Lamellibranchiate Bivalves. The remaining families of Bivalves, and the whole group of Univalves, must be reserved for a future report.

I am desirous that it should be understood that, where I do not express myself to the contrary, my statements are the result of my own researches; and that I am ready to substantiate them by reference to the preparations on which they are grounded, all of which are in my possession.

I shall commence with a brief outline of the researches and conclusions of Mr. Hatchett (Phil. Trans. 1799), and of Mr. Gray (Phil. Trans. 1833); the only two original inquirers on this subject, so far as I am aware, since the time of Reaumur.

The experiments of Mr. Hatchett led him to divide Shells into two classes, the *porcellanous* and the *nacreous*. He stated that those belonging to the former group are composed of carbonate of lime, held together by so small a proportion of animal matter, that, although its presence may be recognized by the effects of heat upon the shell, no membranous film is left after the action of dilute acid upon it. Under the *nacreous* group he placed those shells which, though they do not all exhibit the nacreous lustre, possess an amount of animal membrane sufficiently great for the form of the shell to be more or less perfectly preserved, after the calcareous matter has been completely dissolved away by dilute acid. To such shells the term *membranous* has been subsequently applied with much greater propriety; and of the class of membranous shells, the true *nacreous* form a subordinate division. This distinction, however, cannot now hold good; since all shells, without exception, have a distinct animal basis, as will be shown hereafter.

According to Mr. Gray, another classification of Shells may be founded upon the manner in which the carbonate of lime is deposited in their substance; some shells exhibiting a distinctly *crystalline* fracture, whilst others are *granular* or *concretionary*. Mr. Gray states that, among the crystalline shells, some may be found, in which the carbonate of lime exhibits a *rhomboidal* crystallization, whilst in others it is *prismatic*. I think it will appear from my inquiries, that the calcareous matter in *all* shells is nearly *equally crystalline* in its *aggregation*; and that the particular *forms* which their fracture presents are determined, chiefly if not entirely, by the arrangement of the *animal basis* of the shell, which possesses a more or less highly organized structure.

I shall now proceed to describe the principal varieties of structure which I have met with in the examination of upwards of 400 species of Shells, recent and fossil, selected from all the principal families of Mollusca. When examining recent shells, I have, in nearly every instance, submitted them to microscopic investigation in at least two ways; first, by making thin sections of them, so that their structure might be examined by transmitted light; and second, by examining the animal membrane left after the removal of the calcareous matter by dilute muriatic acid, which I shall name for convenience the *decalcifying* process. In many instances also, I have found the examination of the natural or fractured surfaces of the shell by reflected light, or of the thin laminæ into which many shells will readily split, to afford valuable information. These methods of investigation mutually aid and correct each other; and neither can be prosecuted alone, without much liability to error.

II. *On the Condition of the Calcareous Matter in Shell.*

1. All *thin sections* of recent Shell are *translucent*, except those which contain a large amount of opake colouring matter, or which (as sometimes happens) have a layer of calcareous particles deposited in a chalky or concretionary state between the proper laminæ of shell-structure. This is the case in the common *Oyster*, as pointed out by Mr. Gray; and in many other shells which possess an opake white aspect, such as *Fusus despectus*. But I cannot regard such layers as forming part of the proper structure of the shell; since the particles of carbonate of lime, of which they consist, are not connected by any organic basis.

2. Again, all thin sections of shell possess the power of *depolarizing light*, so that the portion of shell appears bright upon a dark ground, when the

polarizing and analysing plates or prisms are so arranged as to prevent the transmission of ordinary light.

3. From these facts I think we are entitled to conclude, that the calcareous matter of shell is in a state of crystalline *aggregation*, even when no crystalline *forms* are presented by it. The absence of the latter is probably due to the mode in which the calcareous matter is set free from the whole surface at once; so that there is not room (so to speak) for these forms to be generated. This conclusion is strengthened by the remarkable fact, that crystalline forms *do* present themselves under peculiar circumstances. Thus I have met, in the Oyster, with layers incompletely calcified; so that, instead of being covered by a continuous and uniform deposit of carbonate of lime, the membrane was studded with a multitude of minute rhomboidal bodies, varying in size from about the 1-6000th to the 1-2000th of an inch across (fig. 16); the effect of polarized light and of chemical reagents upon which, left no doubt that they are *crystals* of carbonate of lime*. In very thin sections of parts of Cypræa and other porcellanous shells, in which the quantity of animal matter is extremely small, I have frequently seen the apparently-homogeneous calcareous deposit crossed by lines, inclined to each other in such a manner, as to indicate a rhomboidal crystallization in its substance. And in the tooth of *Mya arenaria*, I have seen an appearance which seems to me (from a comparison of it with numerous allied forms of structure) to indicate the crystallization of the carbonate of lime in a *radiating* manner, (the centres being the nuclei of the cells, within which each group of crystals was originally inclosed,) somewhat after the manner of radiating Arragonite or Wavellite (fig. 14).

III. *Of the Animal Basis of Shell.*

4. When a portion of *any* recent Shell is submitted to the decalcifying process, a perfectly definite animal basis remains. This basis may be nothing more than a film of *membrane*, so delicate as almost to elude detection†, but evidently not an amorphous residuum; or it may be a membrane of firmer consistence, presenting regular plications or corrugations; or it may consist of an aggregation of *cells*, having very definite membranous walls, and a more or less regular form. My first division of shell-structures, therefore, is, according to the character of the animal basis, into the *cellular* and the *membranous*; these I shall now proceed to describe in detail.

IV. *Prismatic Cellular Structure.*

5. If a small portion be broken away from the thin margin of the shell of any species of *Pinna*, and it be placed without any preparation under a low magnifying power, it presents on each of its surfaces, when viewed by *transmitted* light, very much the aspect of a honeycomb; whilst at the broken edge it exhibits an appearance which is evidently *fibrous* to the eye, but which, when examined under the microscope with *reflected* light, resembles that of an assemblage of basaltic columns. The shell is thus seen to be composed of a vast multitude of prisms, having for the most part a tolerably regular hexagonal shape and nearly uniform size. These are arranged perpendicularly (or nearly so) to the surface of each lamina, so that its thickness is formed by their length, and its two surfaces by their extremities. A more satisfactory view of these prisms is obtained by grinding down a lamina,

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* It is stated by Wagner, that minute crystals of calcareous matter are to be found in the cartilaginous envelope of *Ascidia mammillata*.—(Lehrbuch der vergleichenden Anatomie, p. 60.)

† When such films have not been visible in the menstruum, I have found them involved in the bubbles that lay on the surface after the effervescence was over.

until it possesses a high degree of transparency; and it is then seen, that the prisms themselves appear to be composed of a very homogeneous substance, but that they are separated by definite and strongly-marked lines of division (fig. 3). In general the substance forming the prisms is very transparent, but here and there is seen an isolated prism, usually of smaller size than the rest, which presents a very dark appearance, even in a section of no more than 1-400th of an inch in thickness, as if the prism contained an opake substance (fig. 6). These dark cells are seen in very great abundance, when we examine a lamina in which the *natural external* surface has been preserved, the reduction of its thickness having been effected by grinding down the under side only; and it is then seen that their degree of opacity varies considerably (fig. 5). To the cause of this appearance I shall presently revert, as it is a matter of some interest in reference to the *formation* of this kind of shell-structure.

6. When a piece of the shell of *Pinna* has been submitted to the action of dilute acid, the carbonate of lime being dissolved away, a consistent and almost leathery membrane remains, which exhibits the prismatic structure just as perfectly as does the original shell; the hexagonal division being seen when either of its surfaces is examined, and the basaltiform appearance being evident on the inspection of its edge. No resemblance can be stronger than that which exists between a layer of this membrane and a corresponding layer of the pith or bark of a plant, in which the cells are hexagonal prisms. In many instances I have been able to detect distinct *nuclei* or *cytoblasts* in all the cells of a naturally thin layer; although, from some cause which I am not able to explain, these are generally invisible (fig. 8). I have often been able to detect them with *reflected* light, however, when I could not distinguish them with *transmitted*. As the nucleus occupies one of the ends of the prismatic cell, it is of course useless to look for it when the natural surface of the lamina has been removed by grinding. The decalcified membrane presents no trace of the opake cells just now mentioned; indeed the small cells which would probably have presented this appearance in a section of the shell, are now, if anything, rather more transparent and free from colours than the rest.

7. The action of dilute acid having thus enabled us to obtain the *membranous* element of shell in a separate state, we are enabled to inquire into the condition of the *calcareous* element, by means of specimens, in which the animal matter has been removed by the long-continued action of water. I am indebted to Mr. S. Stutchbury for an interesting specimen, in which the thick outer layer had become disintegrated during the life of the animal, by the decay of its organic structure, and the prisms of carbonate of lime were left *in situ*, but not in any way held together, so that they could be separated by a touch. On treating these prisms with dilute acid, I have found them encircled by an extremely delicate membranous film; the remainder of the cells in which they were originally formed having been removed by decay. In the fossil *Pinnæ* of the oolite and neighbouring formations, it very frequently happens that the prisms exhibit a similar tendency to come apart, so as to admit of separate examination. It is then seen, that whilst some of them are *truncated* at *both* ends, so that their extremities appear at the two surfaces of the layer which they form, others gradually come to a *point* at *one* end, so that this is lost in the thickness of the layer (figs. 9–11). A careful examination of these prisms, and of their irregularities of form, quite disproves the idea that their shape is due to a prismatic crystallization of carbonate of lime, it being evident that they are *casts* of the interior of organic cells, the shape of which is determined by their mode of origin and formation. The variations in the *size* of the prisms at different parts of their length, accounts

satisfactorily for the varying size of the reticulations as shown on a transverse section of them,—some of the cells being cut across at their thickest, and some at their thinnest part. The very small hexagons which are occasionally seen in the midst of larger ones (fig. 7), are evidently the sections of prismatic cells, which are coming to a pointed termination. Of this fact I shall presently make further use (§ 14).

8. The great thickness of the basaltiform layers in many of the fossil *Pinnæ* (and their allied genera) renders them very favourable subjects for examination of their structure, by a section at right angles to their surfaces. It is then seen that the direction of the prismatic fibres is seldom quite straight. In the same section they are often cut longitudinally in one part, and obliquely or almost transversely in another. Hence, although it is plain from the appearances shown on fracture, or by the disintegration of the shell, that most of the fibres pass continuously from one surface to the other, it is seldom that the whole length of them can be displayed in any one *section*,—one set frequently passing off by a change of direction, and another coming into view. Even to the naked eye, the curvature of these fibres is often sufficiently evident in the large *Pinnæ* and *Inocerami*; a circumstance which may, I think, be regarded as adding weight to the conclusion, that the prismatic character of the fibres is not to be attributed to crystalline action, but to the form of the cells in which the calcareous matter is deposited.

9. The general structure of the outer layers of the shell of *Pinna* (and, as I shall hereafter show, of many other genera) may be thus described:—it consists of a stratum of prismatic cells, usually more or less hexagonal, adherent to each other by their sides, and forming the surfaces of the layer by their flattened terminations. Most of these cells pass continuously from one surface to the other, so that their length corresponds with the thickness of the layer; but some of them end, by acute terminations, in the interior of the layer, when its thickness is considerable (figs. 2 and 10). These cells are filled with carbonate of lime, which give firmness to what would be otherwise a soft membranous stratum. From the universality with which this kind of structure, when it presents itself at all, forms the *external* layers of the shell, and from the complete correspondence between the form and aggregation of its cells, and those of the Epithelium covering the free surfaces of the other membranes of the body, I think we are justified in regarding the *prismatic cellular substance* of shell (which is the term by which I have designated this kind of structure) in the light of a *calcified epithelium*. It would thus correspond with the Enamel of Teeth, to which it is analogous in every respect, save the character of the mineral deposit, and the much larger size of the prisms.

10. A more minute investigation of this structure throws some additional light on the mode in which it is at first produced. When a thin section is made of the shell of *Pinna nigrina* parallel to its surface, it exhibits a beautiful reddish-violet hue by transmitted light, which is not, however, uniformly diffused over the whole section, some parts being commonly almost or completely colourless (fig. 1). This appearance is completely explained by the examination of a thin section made in the opposite direction; and it is then seen that there is an alternation of coloured and colourless strata through the whole thickness of the layer; so that the variations in the hue of the horizontal section are due to the mode in which these strata crop out, one from beneath another (fig. 2). If the section, however, should happen to traverse one layer only, its hue will be uniform throughout; and thus I have sections of the same shell, taken from the same part of it, in some of which the whole is colourless, whilst in others it is uniformly tinted. Now these facts are in-

teresting, as proving, I think, beyond a doubt, that the filling up of these long prismatic cells with carbonate of lime was not accomplished at one *nisus*; and that there must have been *a succession* of deposits, of which some were tinted by the admixture of a coloured secretion, whilst others were left colourless. The *outer* portion of each layer will of course be the part first formed; and the coloured layers are usually most numerous and deeply tinted in its neighbourhood.

11. The idea of a succession of deposits is borne out by a very curious appearance, which is presented by the two elements of the structure, when they are separately examined. The prismatic cells of the decalcified membrane exhibit a series of transverse markings at a small distance from each other, which bear no small resemblance (as Mr. Bowerbank has remarked) to the transverse striæ of muscular fibre. These markings may be best seen by looking at the sides of the cells, in a *vertical* section which has been decalcified by dilute acid; and they impart to the long prisms very much the aspect of the scalariform vessels of plants (fig. 11). But they may frequently be well seen in a *horizontal* section (with or without decalcification), when, as often happens, the direction of some of the prisms is somewhat oblique, instead of being perpendicular to the plane of the section. Markings of a precisely similar nature are seen upon the calcareous prisms themselves, both from recent and fossil shells; and they evidently correspond with those which the cell-walls exhibit.

12. These markings are attributed by Mr. Bowerbank to the existence of a vascular network, by which he supposes each stratum of prismatic cells to be surrounded. He thinks that a network of tubes, passing round each cell, may frequently be seen in the decalcified membrane; and that the slight bulging inwards, which the passage of the tube between the contiguous walls of two cells will give to each of them, is the cause of the marking in question. I cannot but think, however, that this view has been somewhat hastily adopted. In the first place, we know of no instance in which vessels pass in this manner through a cellular structure, except in the adipose tissue of animals, to which the fabric of shell bears no resemblance. I have in vain looked, in many scores of carefully-prepared specimens, for appearances distinctly indicative of the passage of tubes between these cells; but have never succeeded. I can in any one, however, readily produce the appearance figured by Mr. Bowerbank as a vascular reticulation, by throwing the cut edges of the membrane a little out of focus. Moreover, if these tubes have a real existence, they ought to be very evident in the shell, before decalcification; in which I have never been able to find a trace of them, although I have examined more than 100 sections, cut in various directions, of various species of *Pinna* alone. When it is considered that the striæ are seldom more than 1-5000th of an inch apart, and are frequently much less, it is evident that there must be at least 5000 strata of this vascular network in a layer of shell an inch thick. According to Mr. Bowerbank, these strata communicate with each other by vertical tubes passing upwards and downwards from the angles of the reticulations. These also I have failed to see, although I have used every variety of magnifying power and of method of examination. I may mention also that, as will presently appear, I have found numerous instances, in which a tubular structure of great delicacy is readily discernible in Shell; so that I am quite familiar with the appearances which such a structure in *Pinna* might be expected to present.

13. By submitting the *cut edges* of the membranous wall of the prismatic cell to a high magnifying power, under favourable circumstances, I have been able to discover what I believe to be the real cause of the transverse

striation in question. The membrane evidently projects inwards at those parts, not in consequence of being pushed inwards from without, but because *its own thickness* is there increased. This appearance corresponds well with the conclusion already drawn, in regard to the *progressive* formation of each layer of shell; and I am much inclined to believe that each transverse marking indicates a distinct deposit. Whether, during the time when this succession of deposits was taking place, the prismatic cells grew at their bases, and these lines indicate the additions which were progressively made to the length of the cells,—or whether the long prismatic cells, as we now find them, are made up by the coalescence of a number of layers of flat pavement-like epithelium-cells, placed one upon another, and the lines indicate their points of junction,—I do not feel warranted in affirming with certainty, as the question could be only rightly decided by examining the shell in the progress of its formation, which I have not yet had the opportunity of doing. I am much inclined, however, to adopt the latter view; which was suggested to me by Professor Owen. The coalescence of cells, linearly arranged, so as to form a single long cell or tube, is an occurrence with which Animal and Vegetable Physiologists are alike familiar. The idea derives strength from the fact, that I have occasionally met with a layer of prismatic cellular structure of such extreme tenuity, that it was almost impossible to separate it, lying between thicker layers of the same in the shell of *Pinna*. The cells of this layer, instead of being elongated prisms, were flat and pavement-like, resembling the epithelium of serous membrane; and it was in such that I have found the cytoblasts most perfectly preserved (fig. 8). It is hardly to be supposed that this layer was produced by a distinct act of shell-formation, as it would not add in any appreciable degree to the size or solidity of the shell; and it seems probable that it was a supplemental portion, which had not coalesced with the remainder of the layer, of which it should properly have formed a part.

14. The last point to which I shall advert, is one which I have already noticed,—the presence of dark or semi-opake cells in great numbers on the *natural outer surface* of the layers of prismatic cellular substance in the *Pinna* (fig. 5); their presence in a much diminished proportion, and only as small cells, in sections taken from the interior of the layer (fig. 6); and their complete absence (in general at least) from the *natural internal* surface of the layers (fig. 7). I have nearly satisfied myself, that the appearance of opacity is due to the presence of a small quantity of air in or near the extremities of the cells. That this, being enveloped in a substance of so high a refracting power as carbonate of lime, would give the appearance of opacity, is easily understood on optical principles, and is practically well known to the microscopist. Now when we consider that the *exterior* surface, on which this appearance is chiefly seen, is the one furthest removed from that surface on which the carbonate of lime is being poured forth, it does not appear surprising that the calcifying substance should not always find its way to the ends of the cells, but should occasionally leave a void space there. And when it is remembered that the dark cells of the interior of the layer are few and small, and that, as already shown, these small cells are the sections of the acute terminations of prisms which do not pass on to the surface, it is obvious that the same view fully accounts for their occurrence in this situation.

15. Although the prismatic cellular structure has not yet been observed in actual process of formation, yet certain appearances which are occasionally met with in the marginal portions of its newest layers, throw great light upon its mode of growth, and indicate its strong resemblance to cartilage in this respect; for in these situations we find the cells neither in contact with each

other nor polygonal in form, but separated by a greater or less amount of intercellular substance, and presenting a rounded instead of an angular border (fig. 12 *c.*). Upon looking still nearer the margin, the cells are seen to be yet smaller, and more separated by intercellular substance (fig. 12 *b.*); and not unfrequently we lose all trace of distinct cells, the intercellular substance presenting itself alone, but containing cytoblasts scattered through it (fig. 12 *a.*). This appearance has been noticed by myself in *Perna* and *Unio*, and by Mr. Bowerbank in *Ostrea*; so that I have no doubt that it is general in this situation. We may, I think, conclude from it, that the cells of the prismatic cellular substance are developed, like those of cartilage, in the midst of an intercellular substance, which at first separates them from each other; that as they grow and draw into themselves the carbonate of lime poured out from the subjacent surface, they approach each other more and more nearly; and that as they attain their full development, their sides press against each other, so that the cells acquire a polygonal form, and the intercellular substance disappears.

V. *Membranous Shell-substance.*

16. Under this appellation I describe the substance, of which (under various forms) all those shells consist, that do not present the prismatic cellular tissue just described. In this substance no trace of cells can for the most part be discovered; and when they do present themselves, they are usually scattered through it with little or no regularity, and do not form a continuous stratum, when the calcareous matter has been removed by acid. In no shell, even those most decidedly *porcellanous*, have I failed in detecting some membranous basis, although the film is often of extreme tenuity. I believe that there is no shell, in which this kind of structure does not exist under some form; for even where almost the entire thickness is made up of the prismatic substance, as in *Pinna* and its allies, there is still a thin lining of *nacre*, which I shall presently show to be but a simple modification of the ordinary membranous structure.

17. Although I cannot yet speak positively on the subject, still I am much disposed to believe, that in every distinct formation of shell-substance there is a single layer of membrane; and I am further of opinion that this membrane was at one time a constituent part of the *mantle* of the mollusc. The late researches of Mr. Bowman upon mucous membrane, have shown that the essential constituent of this tissue is a delicate, transparent and homogeneous expansion, the free surface of which is usually covered with epithelium-cells, whilst the attached side is in contact with that complex tissue (composed of areolar structure, blood-vessels, lymphatics, &c.) to which the name of "mucous membrane" is commonly applied. This expansion is termed by Mr. B. the "basement membrane;" and it is found, not merely on the mucous membranes, but also on the external surface of the *true skin*, lying beneath the epidermic cells. Now the *mantle* of the Mollusca, being essentially analogous to the true skin of higher animals, may be inferred to possess this element; and if it be periodically thrown off and renewed, we have a case strongly analogous to the formation of the "decidua" in the human uterus. Whether this be or be not the origin of the membranous residuum, which is found after the decalcification of shell, the correspondence between this tissue and the basement-membrane of Mr. Bowman is extremely close. In its simplest condition, the former, like the latter, is a pellucid structureless pellicle of extreme delicacy and transparency, exhibiting no trace either of cells, granules or fibres (fig. 19). I have occasionally found it, however, of a somewhat *granular* appearance, as if formed by the solidification of a thin stratum of fluid, including an immense

number of minute molecules. In other cases, again, I have found it studded here and there with what seemed to be incipient cells. And lastly, I have occasionally found these cells more developed, and forming an almost continuous layer on the surface of the membrane. In this state they somewhat resemble the incipient form of the prismatic cellular substance. These cells may be occasionally seen in sections of the shell itself; and they will be often found in very different degrees of development, even in the corresponding layers of two shells of the same species. Coupling the appearances which I have myself observed with the observations of Mr. Bowerbank on the *formation* of shell, and keeping in view the general doctrines of cell-action, which I have elsewhere endeavoured to develope, I am inclined to believe that these cells are, like the cells of the prismatic cellular structure, the real agents in the production of the shell, it being their office to secrete into their own cavities the carbonate of lime supplied by the fluids of the animal. But whilst the cells of the prismatic cellular structure advance in their development, so as to form a perfect tissue,—the "calcigerous cells," of which we are now speaking, appear to burst or liquefy, and to discharge their contents upon the surface of the subjacent membrane, on which a shelly layer is thus formed. A greater or smaller proportion of these being left entire, and being included in the substance discharged from the rest, would present the appearances I have mentioned as occasionally manifesting themselves in sections of membranous shell-structure, and in the decalcified membrane. Thus in *Mya*, *Anatina*, *Thracia*, and other allied genera, I have met with obvious indications of a cellular structure in sections of the exterior layer of the shell (fig. 15); but I have seldom been able to obtain any distinct layer of cell-membrane (like that existing in the shell of Pinna and its allies) by the action of acid, except in Thracia and Pandora; although traces of scattered cells do present themselves. Hence it is evident that the cells, if they ever existed as such (of which I have little doubt), have ceased to exist; but that their solid contents have been left. The difference between this kind of structure and the regular prismatic cellular substance, will be made evident by a comparison of the two forms delineated in figs. 3 and 15. The sharpness and definiteness of the lines dividing the cells in the former, are in striking contrast with the irregularity of the spaces intervening between the latter. In the shells of the family *Myidæ*, too, I have seen other appearances which fall in with the view just expressed in regard to the "fusion" of cells with each other; these I shall describe more particularly in a future Report; but in the mean time I may direct attention to fig. 13, as most clearly indicating the existence of such a "fusion;" its various stages being evident in the different parts of the same specimen.

18. The Membranous shell-substance presents many curious varieties of aspect, which may be generally accounted for by corresponding diversities in the arrangement of the basement-membrane. Thus it sometimes presents a simple homogeneous character, as if the shelly matter had been uniformly diffused over a plane surface; but this is comparatively seldom the case, for there are few instances in which the shell does not present, in some part of its thickness, an appearance which indicates an unevenness of surface on the part of the basement-membrane (fig. 43); and this appearance is usually found to correspond with the aspect of the membrane after decalcification. Sometimes this unevenness amounts simply to a *corrugation* or wrinkling, closely resembling that of morocco leather. The boundaries of the wrinkles are so strongly marked in some shells, that even the experienced Microscopist may be deceived into the belief that he is looking at a section displaying fusiform cells. Such is the case with the inner layer of the shell of *Patella*. In

all these instances, the *decalcification* of the shell affords a tolerably conclusive test of the real nature of the structure; for the absence of cells in the membranous residuum, coupled with the existence of the corrugations in the membrane itself, clearly indicates its character.

19. In many other instances the membrane is still more gathered up into *plaits* or *folds*, which lie over one another, so that their edges present themselves as a series of lines, more or less exactly parallel. I shall presently show that the peculiarity of *nacreous* structure is dependent upon this kind of arrangement; and that another very remarkable form of it is characteristic of the *Terebratulæ* and their allies.

20. I am at present inclined to believe that a great part of the appearances, which are attributed by Mr. Gray to the rhomboidal crystallization of the carbonate of lime, are really due to the corrugation or plication of the basement-membrane; for there may be noticed in the disposition of the folds, exactly that variation between the different layers, which Mr. Gray has pointed out as resulting from the different directions of the crystallization. Thus in *Cypræa* and its allies, the three layers of shell are easily made to come into view in the same section, and it is then seen that the corrugations of each layer cross those of the adjoining one. A different explanation has been offered however by Mr. Bowerbank; and until I have examined the subject afresh, I avoid expressing a positive opinion on the subject.

VI. *Nacreous Structure.*

21. The superficial aspect of nacre (or mother-of-pearl), and the optical phænomena which it presents, have been examined and described by Sir D. Brewster* and Sir John F. W. Herschel†. My inquiries into its structure will enable me, I think, to give a more satisfactory description of its formation than has yet been offered; and also to explain some of the optical phænomena, which have not yet been fully accounted for.

22. When a thin layer of nacre is submitted to the microscope, its surface is seen to be marked with numerous delicate lines, which traverse it with greater or less regularity: sometimes these lines are almost straight, and run nearly parallel to each other at tolerably regular intervals; whilst in other parts of the same specimen they are seen to follow a more irregular course, and to diverge widely from each other (fig. 17). Sir J. Herschel has not unaptly compared this appearance to that of the surface of a smoothed deal board, in which the woody layers are cut perpendicularly to their surface in one part, and nearly in their plane in another. These lines are seen on the natural interior surface of the nacre, and no polishing obliterates them. Their distance from each other is extremely variable; I have seen them only 1-7500th of an inch apart; but they are usually in much less close proximity.

23. When the nacre-lines are carefully examined, it becomes evident that they are produced by the cropping-out of laminæ of shell, situated more or less obliquely to the plane of the surface. The greater the *dip* of these laminæ, the closer will their edges obviously be; whilst the less the angle they make with the surface, the wider will be the interval between the lines. When the section passes for any distance in the plane of a lamina, no lines will present themselves on that space.

24. As far as I can understand Sir D. Brewster's idea of the structure of nacre, he appears to me to suppose, that it consists of a multitude of layers of carbonate of lime alternating with animal membrane, and that the pre-

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* Philosophical Transactions, 1814; and "Optics" in Lardner's Cabinet Cyclopædia, pp. 115–120.

† Edinburgh Philosophical Journal, vol. ii.

sence of grooves on the most highly-polished surface is due to the wearing-away of the edges of the animal laminæ, whilst those of the hard calcareous laminæ stand out. If each line upon the nacreous surface, however, indicates a distinct layer of shell-structure, a very thin section of mother-of-pearl ought to contain many thousand such layers, in accordance with the number of lines upon its surface. But when the nacre is treated with dilute acid, so as to dissolve away its calcareous portion, this is found not to be the case. The number of layers of membrane bears no proportion whatever to the number of lines upon its surface; and it is impossible therefore to imagine, that the laminations indicated by these lines are so many distinct layers of shell-structure.

25. It is generally difficult to ascertain anything from the examination of the decalcified membrane, as to its disposition in the nacreous structure; since the disengagement of carbonic acid more or less completely unfolds the plaits, of which some indications remain in it (fig. 19): but one shell affords us the opportunity of examining the plaits *in situ*, and thus presents a clear demonstration of the real structure of nacre. The shell I allude to is *Haliotis splendens*, in which, as Mr. Gray has remarked*, a considerable quantity of animal matter intervenes between the layers of nacre. This is not disposed in *spots*, however (as stated by Mr. Gray), but in the form of numerous *plates* of a horny substance, very like tortoise-shell in colour and aspect. As the surfaces of these plates usually follow the curvature of the shell, a plane section will not pass through any one of them for any considerable distance, and consequently its cut portion will appear as an insulated spot. If a piece of this shell be submitted to the action of dilute acid, the calcareous portion of the nacreous layers, which intervene between these plates and hold them together, is dissolved away, and they readily separate. Each horny plate is then seen to be covered on one side with the membranous residuum of the nacre, whilst on the other it is bare,—this surface being applied, in the unaltered shell, to the layer of nacre which adheres to the next plate. *Only a single* layer of nacre-membrane exists between each pair of horny laminæ, and we have thus a most favourable opportunity of studying its disposition. It is generally found that, when the horny plates fall asunder in the dilute acid, some of them exhibit the nacre-membrane in an undisturbed condition, and their surfaces *then exhibit the iridescent lustre, although all the calcareous matter has been removed from the structure.* On looking at the surface with reflected light, under a magnifying power of about 75 diameter, it is seen to present a series of folds or plaits more or less regular (fig. 18); and the iridescent hues which these exhibit are of the most gorgeous description. If the membrane be extended with a pair of needles, these plaits are unfolded, and it covers a much larger surface than before; but the iridescence is then completely destroyed.

26. I think it will be admitted that this is an *experimentum crucis*, in regard to the cause of the iridescence of nacre, demonstrating that the peculiar lineation of its surface (on which the iridescence undoubtedly depends) is due, not to the outcropping of alternate layers of membranous and calcareous matter, but to the disposition of a single membranous layer in folds or plaits, which lie more or less obliquely to the general surface; so that their edges present themselves as lines, at a greater or less distance from each other, according to the direction in which the section traverses them.

27. Besides the images described by Sir D. Brewster, another optical phænomenon has been pointed out by Sir J. Herschel, as presented by mother-of-pearl, when light is reflected from its surface. This he has aptly compared

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* Philosophical Transactions, 1833.

to the minute ripples which cross the surface of the larger waves. I think that my observations furnish the explanation of these appearances. The lines which mark the edges of the plaits are seldom or never quite even, but are more or less wavy. Of these irregularities, some are caused by the minute scratches or indentations left by the polishing material; but these may be readily distinguished by the experienced observer; and there is, besides them, a regular series evidently caused by slight transverse undulations in the plaits themselves, which thus form a secondary series of minute corrugations, lying at right angles with the principal plaits. These secondary corrugations, however, are seldom deep enough to overlie one another, and hence they exhibit no lined edges. I have been able to detect them very readily in the decalcified nacre-membrane, when it has suffered no extension; when it has been in the least degree stretched, however, the secondary corrugations are flattened, and the edges of the primary folds become quite straight. The reason why the optical appearances resulting from this arrangement cannot (as Sir J. Herschel has remarked) be communicated, like those of the primary series, to surfaces of wax, resin, &c., appears to me to be simply this, that the folds are not deep enough to overlap each other, and that thus no lined edges are produced; consequently the corrugations give rise to no inequalities on the polished surface, and cannot communicate any peculiar character to substances impressed upon it.

28. In no nacreous shells that I have examined, have I failed to discover the structure which I have described; and my examination has comprehended examples, both recent and fossil, from all the tribes in which this character presents itself.

29. There are several shells which present what may be termed a *subnacreous* structure, their polished surfaces being covered with lines indicative of folds in the membrane; but these folds being destitute of that regularity of arrangement, which is necessary to produce the iridescent lustre. This is the case, for example, with most of the *Pectinidæ*, also with some of the *Mytilaceæ*, and with the common *Oyster*. It is easy to understand, therefore, why there should be a variation in this respect within the limits of a single genus. Thus in *Ostrea* there is usually no perfect nacre, yet there are species which are truly nacreous. On the other hand, in *Mytilus* there is usually a truly nacreous interior; yet there are species in which this is wanting. When so very slight a difference in the arrangement of the folds will produce this variation, it is not surprising that it should occur among the species of the same genus. A want of transparency, also, appears to be one cause of the absence of the iridescent lustre. Thus in a very thin layer of the shell of *Ostrea edulis*, the nacreous lineation is here and there very characteristically shown; yet the shell possesses no iridescence, partly in consequence, I am inclined to think, of the presence between its layers of the chalky deposits formerly mentioned (§ 1), which can neither transmit nor reflect light.

VII. *Tubular Structure.*

30. All the different forms of membranous shell-structure are occasionally traversed by *tubes,* which seem to commence from the inner surface of the shell, and to be distributed in its several layers. These tubes vary in size from about the 1-20,000th to the 1-2000th of an inch; but their general diameter, in the shells in which they most abound, is about 1-4500th of an inch. The direction and distribution of these tubes are extremely various in different shells; in general, where they exist in considerable numbers, they form a network, which spreads itself out in each layer, nearly parallel to its surface; so that a large part of it comes into focus at the same time, in a section

which passes in the plane of the lamina (fig. 20). From this network some branches proceed towards the nearer side of the section, as if to join the network of another layer; whilst others dip downwards, as if for a similar purpose. The most characteristic examples of this structure which I have met with are to be found in the outer yellow layer of *Anomia ephippium* (fig. 40), the external layer of *Lima scabra*, and in *Chama florida*. In other instances, the tubes run at a distance from each other obliquely through the shelly layers, and they are then usually of large size. This is the case for instance in *Arca Noæ*, and *Pectunculus*. In no cases have I seen any such variation in the size of the tubes of the same shell, as would convey the idea of their resemblance to blood-vessels; and even where a division occurs, the size of each of the branches is usually equal to that of the single trunk. Sometimes these canals are quite straight, whilst in other instances they are sinuous. That they are not mere channels or excavations in the shell-substance, is proved by the fact that they may be seen in the decalcified membrane (fig. 41). I have frequently seen in them indications of a cellular origin, as if they had been formed by the coalescence of a number of cells arranged in a linear direction; and I find that Mr. Bowerbank has come to the same conclusion.

31. The tubular structure is usually found only in the ordinary membranous shell-substance; in fact, I have seldom observed it in the nacre, except where the tubes penetrate this, to be distributed in a layer external to it, as is the case, for example, in *Anomia* and *Trigonia*. I have nowhere found it coexisting in the same shell with any great amount of prismatic cellular substance; consequently it is for the most part absent in the *Margaritaceæ* and *Nayadeæ*, and but very slightly manifested in the true *Ostraceæ*. In most of the families of Bivalves, however, in which the lobes of the mantle are united, some traces of it may be detected; though these are often very scanty. There is less regularity in regard to this character, than in respect to most others furnished by the microscopic examination of the shell. Thus I have found a little collection of tubes in one spot of the nacre of an *Avicula*, in no other part of which did I meet with any; and I have frequently found one species of a genus extremely tubular, whilst another, closely allied to it, was almost or entirely destitute of tubes. Nevertheless, in conjunction with other characters, I consider that the presence or absence of this structure may often afford valuable assistance in determining the position of an unknown specimen. Of this I shall presently adduce a striking example.

VIII. *Cancellated Structure.*

32. I give this denomination to a peculiar structure closely resembling the cancellated texture of bone, which is remarkably characteristic of that very peculiar and perplexing group,—the *Rudistes*. I can scarcely describe this structure so well, as by comparing it with the prismatic cellular structure of *Pinna* and its allies, upon a large scale; with this important difference, however, that in this cancellated structure the prismatic cells are not solid but hollow*. It is true that in many specimens of Hippurite and Sphærulite, the cancelli are found to be completely filled with carbonate of lime; but there are appearances about this deposit, which lead to the belief that it is the work of subsequent infiltration; and this view is confirmed by the fact, that the *Rudistes* of the Chalk are commonly found with their cancelli empty. In what manner these minute chambers were occupied during

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* This structure has been described by Mr. Gray in the Magazine of Zoology and Botany, vol. ii. p. 228.

the life of the animal, it is impossible now to say; as there is no existing group, to which the *Rudistes* seem to bear any close resemblance. The shape of each is usually that of a very short hexagonal prism, terminated at each end by a flat partition: consequently a section in one direction will exhibit the walls of the chambers disposed in a hexagonal network (fig. 22); whilst, 23 when the section passes in the opposite direction, the transverse partitions come into view (fig. 23). The cancellated structure is externally and internally covered with a shelly plate, in which no perforations whatever can be 24 seen. It is difficult to imagine, therefore, how any communication could have existed between the animal contained within the shell, and the cancellated structure which forms its thickness.

33. The only approaches to this structure, so far as I am aware, presented by any recent shells, are to be found in the irregular cancellated structure of the base of some of the sessile Cirrhopods; and in a similarly irregular cancellated structure, which has been described by Mr. Gray* as existing between the laminæ of an undescribed species of Oyster, named by him *Ostrea purpurea.* I have not myself met with anything at all to be compared with it among the shells of ordinary Mollusca; and I cannot but think that its existence, as nearly the sole component of their shells, marks out the *Rudistes* as a group altogether distinct from them. The position which I should be myself inclined to assign to them, from the structure of the shell, is between the *Ostraceæ* and the sessile *Balani*; and I believe that the most complete information we possess on the character of the animals, would lead to the same conclusion.

34. The presence of this structure in any fossil, whose situation is doubtful, appears to me a sufficient reason for referring it to the group of *Rudistes.* Thus from finding it in *Pleurorhynchus Hibernicus* (figs. 24, 25), I should almost unhesitatingly assign this position to that shell, notwithstanding its strong resemblance in form to some of the *Cardiaceæ.* It has not the least correspondence, however, to the *Cardium cardissa,* or to any of the *Cardiaceæ* that I have examined, in regard to the structure of its shell, which entirely consists of cancellated texture,—the cancelli being formed by the intersection of planes at right angles to each other. When the shell disintegrates, the *casts* of these cancelli, which are produced by the infiltration of carbonate of lime, are disposed to separate from each other; and thus a layer of isolated parallelopipeds are found in place of the shell.

35. Having now described the principal component elements, of which the shells of Mollusca are made up, I proceed to detail the results of my inquiries into the combination of these, in the several groups which altogether form this sub-kingdom. From what has been already stated, the question naturally presents itself, how far the elementary structure of the shell may furnish characters of importance in classification and in the determination of fossils. My inquiries, so far as they have yet proceeded, tend to establish this position, *that where a recognizable and constant diversity presents itself in the elementary structure of the shell among different groups, that diversity affords characters, which are to a very high degree indicative of the natural affinities of those groups.* It is not always that peculiarities sufficiently distinctive present themselves, even between what are regarded zoologically as distinct families; but where a marked diversity *does* exist, I believe that it will always be indicative of the affinities of the animal. Thus the conformity in structure between all the shells of one natural family is usually so close, that any strongly-marked difference in a particular genus would make me hesitate in

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* *Loc. cit.*

admitting it into the group. I think it well at once to premise, that the characters derived from the intimate structure of the shell are not likely to serve for the distinction of *species* from each other, and that they will not often distinguish *genera*; but for the separation of some *natural families*, I believe that they will furnish the best *single set of characters* that the naturalist possesses, especially among particular groups, in which the application of other characters is very uncertain.

IX. *Brachiopoda.*

36. The shells of the *Brachiopoda* or *Palliobranchiata* (Owen) present many interesting objects for inquiry; their structure is, in almost every instance, quite distinct from that of the shells of the Lamellibranchiate bivalves; so that, as I shall presently show, even amorphous fragments of shell may be referred with certainty to this group, when not altered by metamorphic action. I have recognized in the shells of *Brachiopoda* two leading types of conformation; one of which is a peculiar variety of the *plicated membranous* structure; whilst the other is an equally peculiar form of the *tubular*. The former occurs in the genus *Terebratula* and its allies, the latter in *Lingula* and *Orbicula*.

37. The shell of *Terebratula psittacea*, which (for a reason presently to be specified) I shall take as a type of the first of these structures, is remarkable for its divisibility into thin micaceous plates, which may be split into laminæ of extreme tenuity. I do not know any one of the Lamellibranchiate bivalves whose shell corresponds with it in this respect, except *Placuna* and *Anomia*, which evidently verge towards the *Brachiopoda.* This facility of lamination characterizes a large number of the fossil species of the group; especially those which correspond with the one now under consideration, in its peculiar characters. The natural laminæ thus obtained frequently afford better subjects for microscopical investigation than can be procured by making sections in the ordinary manner. When these laminæ are examined with a good microscope, they are found to present a most remarkable and characteristic appearance; they are traversed by a very regular series of lines, usually nearly straight, but sometimes slightly curved, and running quite parallel to each other (figs. 27, 28). The distance of these lines from each other averages about 1-2000th of an inch, and from this average I have never found any very wide departure,—the greatest distance I have met with being in *Terebratula octoplicata*, where the space between them is about 1-700th of an inch.

38. When the broken extremities of these natural laminæ are examined, it is seen that the lines in question are produced by sharp foldings of the shelly layer, which foldings are parallel to each other; and this view is confirmed by examination of the decalcified membrane, of which only one continuous stratum exists in each lamina.

39. When the *natural internal* surface of the shell is examined, a very beautiful appearance is presented by it; a most regular *imbricated arrangement* is seen, exactly resembling a tiled roof, in which the lower margins of the tiles are rounded, instead of being quadrangular (fig. 29). If a portion of the surface be slightly rubbed down, so that the connection of these tile-like markings with the interior structure can be traced, it is seen that they are the extremities of the longitudinal folds just mentioned, each row of them belonging to one lamina, and a series of these laminæ cropping-out, one beneath another.

40. When artificial sections, instead of the natural laminæ or surfaces of this shell, are examined, a great variety of appearances will be presented, according to the mode in which the plane of the section traverses the plaited

surface (fig. 30). These appearances, however, are all reconcileable with the description which I have given of this peculiar kind of structure, and are easily recognized as appertaining to the group in question, and to this alone.

41. When any other *recent* species of *Terebratula* is examined, an additional peculiarity is observed; this consists of the presence of a large number of *perforations* in the shell, generally passing somewhat obliquely from one surface to the other, and terminating by an orifice at each (figs. 33–39). The size of these perforations is sufficiently great, to enable them to be detected with a hand-magnifier, as minute punctations on the surface; and as such they have been recognized by many, who have made this group their particular study. I am not aware, however, that the fact of these punctations being the orifices of large canals, passing from surface to surface of the shell, has been previously noticed. The diameter of these perforations in the shells of recent *Terebratulæ* varies from about ·0006 to ·0024 of an inch; they are readily distinguished in the decalcified membrane, and are seen to be lined by a tubular prolongation from it. Of their object or purpose I can give no definite account; and not having had the opportunity of examining a recent specimen with the animal preserved, I am unable to speak confidently as to the degree of connection, which these passages have with the mantle and with the interior of the shell.

42. Having examined all the recent *Terebratulæ* in the British Museum, and in the collection of Mr. Cuming, I feel able to state as a general fact, that all these species possess this remarkable character, with the exception of *Terebratula psittacea*; which, in the opinion of many, has *other* distinctive characters of its own, quite sufficient to separate it from the group. Upon turning my attention to the fossil species, however, a difference in this respect soon became obvious; for whilst some presented these perforations very distinctly, others were found entirely destitute of them. The presence or absence of the perforations cannot be detected in the fossil species, as in the recent, by the examination of the *surface* of the shell with a hand-magnifier; since, owing to the filling-up of the passages with the fossilizing material, their extremities are not sufficiently distinguishable from the surrounding surface. Hence, in order to determine the existence of this character in the fossil species, it is necessary to make a *section* of the shell. Believing that it must have some intimate relation with the structure and habits of the animal, and that it must consequently be a character of zoological importance, I have endeavoured to carry out this kind of examination to an extent sufficient to test its value; and the following is the result of the examination of thirty-five fossil species of the genus *Terebratula*:—

Perforated.

Acuta.
Ampulla.
Bidens.
Biplicata.
Bullata.
Caput serpentis.
Carnea.
Detruncata.
Digona.
Fimbria.
Globata.
Hemisphærica.
Oblonga.

Not Perforated.

Coarctata.
Concinna.
Depressa.
Inconstans.
Latissima.
Nuciformis.
Obsoleta.
Octoplicata.
Plicatella.
Reticularis.
Rostrata.
Spinosa.
Subrotunda.

Perforated.	*Not Perforated.*
Obovata.	Variabilis.
Ornithocephala.	Subplicata.
Ovata.	Tetraedra.
Perovalis.	Wilsoni.
Sphæroides.	

This list will enable any one conversant with the genus to see, that, with scarcely an exception, the *perforated* species are *smooth*, or but *slightly plicated*, not exceeding in their plication the *Terebratula caput serpentis*, which is, I believe, the most plicated of the recent species; whilst the *non-perforated* species are *deeply plicated**. Besides the species named in this list, I have examined about ten other species of non-plicated *Terebratulæ*, whose names I was unable to ascertain; they all agreed with the other non-plicated species, in the possession of the perforations.

43. Among the genera most nearly allied to *Terebratula*, I have usually found a similar variation. Thus, *Orthis canalis* and *Orthis* (*Spirifer*, Phil.) *filiaria* present exactly the same structure as the perforated *Terebratulæ*; whilst *Orthis hemipronites*, *Orthis resupinata*, and another species from the Silurian formation, Ohio, are destitute of perforations.

44. In *Spirifer*, again, the perforations are present in some of the species, and absent in others. For want of good specimens I have not been myself able to examine many species of this genus; but I have found the perforations very well marked in *Spirifer Walcotii* of the Lias, whilst they are absent in *Spirifer cuspidatus* and another Mountain Limestone species, and in a species from the Devonian formation at Hudson's Bay. I learn from Mr. Morris, that he has remarked the punctations in the Spirifers of the Silurian and later secondary strata, but not on those of the mountain limestone; which circumstance he attributed to the metamorphic condition of the shell in the latter. I am satisfied, however, that such is not the case; since, although the structure of the shell is often obscured by this action, I possess sections in which it is extremely well preserved, and in which there is an evident *absence* of the perforations.

45. In no *Atrypa*, however, have I met with perforations. The species I have examined are *Atrypa affinis*, *A. pugnus*, *A. lineata*, *A. galeata*, and a crag species closely allied to *Terebratula psittacea*, if not identical with it.

46. In *Pentamerus Knightii* I have found the structure characteristic of the group, but without perforations.

47. The structure of the shells of *Lingula* and *Orbicula* is equally peculiar, but very different from that which has been now described. These shells are almost entirely composed of laminæ of horny matter, which are perforated by minute tubuli, closely resembling those of ivory in size and arrangement, and passing obliquely through the laminæ (fig. 22). Near the margin of the shell, these tubuli may be seen lying nearly parallel to the surface.

X. *Placunidæ.*

48. This family has been separated by Deshayes from the *Ostraceæ*, and constitutes, according to his views, "a descending and lateral line, really intermediate between the ordinary Bivalves and the Brachiopoda." The propriety of such an arrangement is completely borne out by the microscopic structure

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* There are one or two apparent exceptions to this, as the case of the *Terebratula subplicata*, in which the plications are very slight; but this is thought by Mr. Morris to be the young of a deeply-plicated species; and the same explanation will probably apply to other cases.

of the shells; for *Placuna* and *Anomia* agree in several particulars, in which both differ from the *Ostraceæ*. The principal part of the shell of the *Placunidæ* consists of true nacre, the laminæ of which are peculiarly separable from each other, thus in some degree corresponding with *Terebratula* and other Brachiopoda. In the Oyster, the shelly layers are more divisible than they are in most other Conchifera, and so far it approaches the *Placunidæ*; but this divisibility is not nearly so great as in the latter. In the form of the nacreous lineation, too, the *Placunidæ* show more resemblance to *Producta* than they do to the ordinary Conchifera. Their chief point of distinction from the *Ostraceæ* is the entire absence of the prismatic cellular structure which characterizes the latter, and the presence, in its stead, of a tubular structure which is found in the nacre itself of *Placuna* and *Anomia,* but more particularly in the yellowish external coat of the upper valve in the latter genus (figs. 40, 41). The tubuli are about 1-2000th of an inch in diameter; they sometimes form a network parallel to the laminæ, and sometimes dip down and penetrate them obliquely or vertically; the wavy direction of the tubes is particularly evident in these shells. By these characters I should have no difficulty in identifying a small fragment of a shell belonging to this family, as I know no other shells which have so regular a distribution of large tubes in their nacreous layers.

XI. *Ostraceæ.*

49. This family now contains only the genera *Ostrea* and *Gryphæa,* between which there is a very close resemblance in general characters, so that it is doubted by many conchologists whether they are really distinct, the one passing gradually into the other. This correspondence exists also in their microscopic structure; in both we find a layer of prismatic cellular substance, in which the cells are very obliquely arranged, forming the margin of each lamina (fig. 44), whilst the general structure of the shell is subnacreous (§ 29). Between the recent *Gryphæa* and *Ostrea,* I have not been able to detect any difference; but in the *Gryphæa incurva* of the lias, I have found the nacre perforated by scattered tubes, of which no trace exists in *Ostrea edulis.*

XII. *Pectinidæ.*

50. In the several genera of this family, the structure of the shell is almost exclusively *membranous.* There are generally two very distinct layers, an inner and outer; but there is no essential difference in their structure, the chief point of distinction being usually in their *colour,* as in *Pecten* and *Spondylus.* I have occasionally met with traces of cellular structure, especially on the external surface of the shell; but I am not inclined to believe that these are to be regarded as constant, or as peculiarly characteristic of the group (fig. 42). No distinct cellular layer can be obtained by the decalcification of the shell; but cells are seen here and there scattered among the folds of the basement-membrane. Hence I am inclined to regard them simply as the remains of the original calcigerous cells, by which the shell was at first formed.—The most characteristic feature of the shells of the *Pectinidæ* is the coarsely-corrugated structure which they exhibit, both in their inner and outer layers (fig. 43): there is also, in some instances, an extremely delicate corrugation, visible only with a high power, and giving to the shell the appearance of possessing a delicate fibrous texture. Both these arrangements are seen in the decalcified membrane, as in the shell itself. In some shells of this family there is a very remarkable amount of *tubular* structure; in fact, I have nowhere found a more characteristic example of it than in *Lima scabra,* but it is not constantly present even in species of the same genus.

51. We shall hereafter find that this corrugated structure, with a greater or

less amount of tubular perforation, is characteristic of several other families of Lamellibranchiate bivalves, which have the mantle wholly or partially closed; and it would not, therefore, serve by itself to distinguish a fragment of a shell of this family from those alluded to. But it is *quite sufficient* to distinguish a shell of this family from any of the neighbouring families, to which, in its general characters, it might possess an affinity. The following is a characteristic example of its use:—A shell was described by Prof. Philips, in his 'Geology of Yorkshire,' as an *Avicula*, which had been previously described by Messrs. Young and Bird as a *Pecten*. The same species, or one closely allied to it, found near Bristol, was described by Mr. S. Stutchbury as an *Avicula*; he not being at the time aware, that it had been met with and described elsewhere. The mixture of characters is such, as would sanction its being placed in either group, according to the relative value attached to them. Thus, in the form of its hinge it is most allied to *Avicula*, whilst in the flatness of its under valve, and in the disposition of its costæ, it rather corresponds with the *Pectens*. The intimate structure of the shell here serves, I think, to decide the point; for we find no trace of either the prismatic cellular substance or the nacre, which are characteristic of *Avicula*; but we meet, on the other hand, with the coarsely-corrugated and somewhat tubular structure of the *Pectinidæ*.

XIII. *Margaritaceæ*.

52. I employ the above designation of this family, because I believe it to be the one most applicable to the genera I include in it, which are the following:—*Perna*, *Malleus*, *Crenatula*, *Vulsella*, *Avicula* and *Pinna*, with the addition of the fossil genera *Gervillia*, *Inoceramus* and (I presume) *Catillus**. All the genera thus associated together exhibit a remarkable uniformity as to the structure of their shells,—the exterior being composed of prismatic cellular substance, and the interior of true nacre,—both of which structures here present themselves in their most characteristic form. There is no difference whatever, that I have met with, except as to the size of the cells, between the elementary structure of any of these shells. This difference is often very considerable; thus the average diameter of the hexagonal cells of the large fossil *Pinna* is about 1-100th of an inch, whilst that of the cells of a small (unnamed) species of *Vulsella*, kindly presented to me for examination by Mr. Cuming, is about 1-2800th of an inch. One cell of the former would contain, therefore, in its area, about 784 of the latter. In three species of recent *Pinna* which I have examined, the average diameter of the cells has been found very nearly the same, namely, 1-500th of an inch. One of these, however, shows a remarkable difference in the size of the cells at the *exterior* and *interior* of each layer, the average of the former being about 1-380th of an inch, whilst that of the latter is about 1-833rd: this difference is due to the fact, that several of the cells of the superficial part of the layer are not prolonged through its thickness, but cease near its middle, as shown by examination of the vertical section, so that there is room for the enlargement of the others. In the genera *Perna*, *Avicula* and *Malleus*, I have found more variation in the size of the cells in the same shell than in the preceding; a layer of much smaller dimensions than the average, being generally found where this tissue comes in contact with the nacreous substance (figs. 45–50).

53. Although the genus *Pinna* has been placed by nearly all Conchologists in the family *Mytilaceæ*, yet I have ventured to associate it with the other genera I have named, on account of its close conformity with them in the structure of its shell, and its entire difference in this respect from the true *Mytilaceæ*. And this alteration of its position seems justified by a careful

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* I have not had an opportunity of examining this genus.

comparison of the *general characters* of the animal, with that of *Avicula* on the one hand, and *Mytilus* on the other. In *Mytilus* there are always two adductor muscles, the anterior very small, the posterior much larger; the lobes of the mantle are united posteriorly at one point, so that there is a single anal siphon; the aperture of the mouth is not furnished with papillæ; and the ligament is altogether external. In *Pinna* there are still two unequal adductor muscles; the lobes of the mantle have no posterior commissure (though partly united along the back), and consequently there is no anal siphon; the mouth as well as the lips are covered with membranous papillæ; the ligament is very narrow and elongated, often covered by a thin testaceous lamina, and loses almost all the characters of the external ligaments. In *Avicula* there is no longer any anterior adductor muscle; there is no posterior commissure of the mantle; the mouth is furnished with papillæ, and the ligament has no longer any of the characters of external ligaments, entirely resembling those of the other *Monomyaria*. The animal of *Perna*, so far as it is known, appears to be very closely allied to that of *Avicula*. Hence the only important character by which *Pinna* is connected with *Mytilus*, is the presence of an anterior adductor muscle; but against this are to be set the want of the posterior commissure of the mantle, the difference in the position of the ligament, and the presence of papillæ on the inner surface of the mouth and lips,—in all which points there is a much closer approximation to *Avicula*. Thus we see how correct is the determination which would have been formed from the sole consideration of the structure of the shell; and even if we consider this but as a single character, to be taken into account with others in the determination of the position of the genus, I think it difficult to resist the preponderance of evidence for detaching *Pinna* from the family *Mytilaceæ*, and for uniting it with the *Margaritaceæ*.

XIV. *Nayadeæ*.

54. Although this family is usually separated widely from the *Margaritaceæ* by systematists, there appear to me many points of resemblance between them. Contrary to Lamarck's statement, the lobes of the mantle in both *Unio* and *Anodon* are entirely open along their whole extent, and the channel which forms the anal passage is made up of the two branchial laminæ, which are there adherent together. Now it is extremely interesting to find that in this group, which conducts us so remarkably from the Lamellibranchiata with the lobes of the mantle *entirely open*, to those in which it is *closed*, the prismatic cellular structure so characteristic of the former division is still found, but in small quantity. The principal part of the shell is nacreous; and the prismatic cellular structure forms but a very thin layer beneath the periostracum (fig. 51). It is to this that the dead-white aspect of the shell is due, when the epidermis has been frayed off (as it often is during the life of the animal, especially near the umbo) without the nacre being brought into view. I can discover no difference between *Unio* and *Anodon* in the microscopic characters of the shell; and consequently can offer no objection on this score to the reunion of these two genera, as proposed by M. Deshayes.

55. In connection with these last families, I may allude to the structure of the curious genus *Etheria*; in regard to the place of which, there is not yet an agreement amongst systematists. By many Conchologists it has been arranged among the *Chamaceæ*, chiefly on account of its tendency to attach its lower valve to solid bodies. Its removal from these, however, has been proved to be required by additional knowledge regarding the structure of the animal. M. Deshayes seems inclined to rank it among the *Nayadeæ*; M. de Blainville thinks it should be associated with the *Margaritaceæ*. The lobes of its mantle are entirely open, but there is an anal passage formed by the adhesion

of the branchiæ, as in *Unio*; and, as in the *Nayadeæ*, there is a large foot. When we add to these characters the attachment of the shell by one of its valves, as in *Ostraceæ* and *Chamaceæ*, the assemblage becomes very perplexing. The microscopic structure of the shell here affords, I think, valuable aid (fig. 52). The prismatic cellular structure here exists in large amount, as in *Pinna*; and the interior is nacreous or sub-nacreous. In these respects it entirely differs from the *Chamaceæ*, in which there is not a trace of prismatic cellular structure, and in which the inner layer has characters which that of *Etheria* does not possess.

56. In all the preceding families, the lobes of the mantle are disunited; and it is very interesting to find how completely the Prismatic Cellular substance is restricted to the group thus constituted. The only approaches to it, which I have met with in other Bivalve Mollusca, are among the family *Myidæ*; and it is only in the very aberrant genus *Pandora*, that it shows itself in a truly characteristic form. Of this group I should be disposed to take the *Margaritaceæ* as the typical or central family. From these we might pass off towards the Brachiopoda on the one hand, by the true *Ostraceæ*, which conduct us towards the *Placunidæ*. Again, by *Avicula* and *Pinna*, we are led towards the *Mytilaceæ*. By *Etheria* we are conducted to the *Nayadeæ*, and these lead us towards the *Chamaceæ*. The most aberrant family, in respect to the structure of the shell, is that of *Pectinidæ*, in which the prismatic cellular structure is entirely absent, whilst there is also an absence of the true nacreous character. Now although the general structure of the *Pectinidæ* is not usually regarded as widely different from that of the *Ostraceæ*, their habits depart most widely from those which prevail in the group; for while the Oysters are fixed by the adhesion of their shells, and the *Margaritaceæ* by a byssus, the Pectens are usually free, and seem to possess more locomotive power, together with a more complete sensory apparatus, than any others of the group. It seems to me that, in these respects, they have a relation of *analogy* with the *Cardiaceæ*: and if such a relation exist, it is remarkably borne out by the intimate structure of the shell, which is closely allied in these two families; as well as by that ribbed surface, which is well known to be characteristic of its exterior, at least in the typical genera of each family.

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Report on the British Nudibranchiate Mollusca. By JOSHUA ALDER *and* ALBANY HANCOCK.

THE *Mollusca Nudibranchiata* of Cuvier, although forming a small order in the class *Gasteropoda*, are sufficiently peculiar in their characters and interesting in their zoological relations to allow of their being reported upon separately from the extensive class to which they belong. Their interest in a physiological point of view has also been much increased lately by the researches that have been made into their structure and mode of development. The anatomical researches of M. de Quatrefages have disclosed, according to his views, so many peculiarities of conformation in some of the species, that he has been induced to detach a considerable portion of this order, and, uniting them with some other Mollusca rather dissimilar in external appearance, to institute for them a new order, which he has called *Phlebenterata*. Not entirely coinciding with the views which M. de Quatrefages has taken, we shall content ourselves in the present report with considering the *Mollusca Nudibranchiata* of Cuvier as still forming one entire group, divisible into two sections, distinguishable from each other by external characters, and probably equally so by physiological peculiarities, the limits of which have not yet been ascertained in the several genera.

The little animals forming this interesting group were long neglected by naturalists, and were scarcely known to any of our earlier writers. Six species only were described by Linnæus in the twelfth edition of his 'Systema Naturæ.' These were included in the class *Vermes*, and formed the genera *Doris*, *Scyllæa* and *Tethys*. Müller paid more attention to them. Fourteen species are published in his 'Zoologia Danica,' the figures and descriptions of which, considering the time at which they appeared, are good. Notwithstanding the contributions of Müller, Fabricius and some others, these animals still continued a neglected tribe, until the appearance of the celebrated memoirs of Cuvier, published in the 'Annales du Muséum,' formed a new era in their history, and laid the foundation of those enlightened views of their structure and affinities which were carried out in his 'Règne Animal,' where the order *Nudibranchiata* was first instituted for their reception. It is to be regretted however that so few species were known even in Cuvier's time, and that he was obliged to have recourse to specimens in spirits for his descriptions. So far as their anatomy is concerned the disadvantages arising from this circumstance were not greatly felt, but those only who have seen these animals alive can know how very imperfect an idea of their external characters specimens preserved in spirits can convey. Considering the early period at which the British naturalists of the Linnæan school applied themselves to the study of species, we are surprised to find how little was effected in this department. Pennant published his 'British Zoology' in 1777, which contains just three species of *Nudibranchiata*, under the names of *Doris Argo*, *D. verrucosa* and *D. electrica*. The latter has not since been recognised. No further attention appears to have been paid to these animals until Colonel Montagu, to whom we are so deeply indebted for his contributions to British zoology, published figures and descriptions of several species found on the Devonshire coast in the Linnæan Transactions. In 1807 Dr. Turton published his 'British Fauna,' where nine species were described, one only of which appears to have been introduced from personal observation; three are those of Pennant and five of Montagu. The whole number of species described by Montagu is twelve, published at different times between 1802 and 1811. For more than twenty years afterwards scarcely anything was done in this department. A few species collected by Dr. Leach are preserved in the British Museum, and some additional species observed by Dr. Fleming and other Scottish naturalists appeared in his 'British Animals', published in 1828, at which time the number of species, including Pennant's and Montagu's, only amounted to twenty. Dr. Johnston's excellent monograph on the Scottish Nudibranchiata appeared in the first volume of the 'Annals of Natural History' in 1838. This treatise gave a new impetus to the study of the order, and with it the first adequate knowledge of the British Nudibranchiate Mollusca may be said to have commenced. An anatomical and physiological account of the animals comprised in the order was given as far as then known, and an attempt was made to extricate the synonyms from the confusion in which they had long been involved,—a task of no easy accomplishment, but necessary to remove a chief obstacle to the study of these animals. This monograph, which was entirely confined to Scottish species, contains descriptions of twenty-one species, ten of which were new to Britain. In the extensive researches that Professor Edward Forbes has made among the *Invertebrata* of our shores, and the many new species that he has added to our Fauna, the *Nudibranchiata* were not forgotten; nine or ten species have been added by this gentleman in different publications, and Mr. Thompson of Belfast, whose success in the cultivation of Irish zoology is so well known, has added at least an equal number. During the time that your reporters have paid attention to the subject, it has also been their good fortune to meet with many new species. Those published by them in the 'Annals of Natural History,' at different times during the last three years, amount to thirty-one species.

The present number of known British species, making allowances for some erroneously raised to that rank, may be stated at seventy-five, which are distributed in the following genera:—

Doridæ.		*Tritoniadæ.*	
Doris	18	Tritonia	3
Goniodoris	4	Melibœa	4
Polycera	5	Proctonotus	1
Thecacera	1	Eubranchus	1
Euplocamus	1	Eolis	33
	—	Pterochilus	1
	29	Calliopæa	2
		Alderia	1
			—
Total	75		46

This number far exceeds that of any other country. In the present imperfect state of our knowledge it would be impossible to give an accurate statement of their geographical distribution on our shores. The attempt which we shall now make must therefore be considered little more than an approximation to such a result. For this purpose we shall consider it sufficient to divide the coast of the British Islands into three principal districts, viz.—

1st. The north and east. This division will comprise the north and east coast of England and Scotland, which may be expected to approximate to the character of the Fauna of northern Europe and the North Sea.

2nd. The south, including the whole of the south coasts of England and Ireland. This division may be expected to show some indications of the Fauna of southern Europe.

3rd. The west, including the west coast of England, the south-west of Scotland, and the whole of Ireland, with the exception of the southern coast. This division will be found to be of a mixed character, uniting some of the characters of both the former with features peculiar to itself.

	1	2	3
DORIDÆ.			
1. Doris tuberculata, *Cuv.*	*	*	*
2. coccinea, *For.*	...	*	*
3. flammea, *A. and H.*	...	...	*
4. obvelata, *John.*	*	...	*
5. repanda, *A. and H.*	*	...	*
6. mera, *A. and H.*	*		
7. muricata, *Mull.*	...	...	*
8. aspera, *A. and H.*	*	*	*
9. ulidiæ, *Thomp.*	...	...	*
10. bilamellata, *Linn.*	*	*	*
11. affinis, *Thom.*	...	...	*
12. depressa, *A. and H.*	*	*	
13. pilosa, *Gm.*	*	*	*
14. similis, *A. and H.*	*		
15. lævis, *Linn.*	*		
16. sublævis, *Thom.*	...	...	*
17. quadricornis, *Mont.*	...	*	
18. Maura, *Forb.*	...	...	*
19. Goniodoris nodosa, *Mont.*	*	*	*
20. marginata, *Mont.*	...	*	*
21. elongata, *Thom.*	...	...	*
22. emarginata, *For.*	...	...	*
23. Polycera quadrilineata, *Mull.*	*	*	*
24. typica, *Thom.*	...	...	*
25. ocellata, *A. and H.*	*	*	*
26. cristata, *Ald.*	*	*	*
27. citrina, *Ald.*	*	...	*
28. Thecacera pennigera, *Mont.*	...	*	
29. Euplocamus claviger, *Mull.*	*	*	*
TRITONIADÆ.			
30. Tritonia Hombergii, *Cuv.*	*	*	*
31. plebeia, *John.*	*	*	*
32. arborescens, *Fab.*	*	...	*
33. Meliboea fragilis, *For.*	*	*	*
34. coronata, *John.*	*	*	*
35. pinnatifida, *Mont.*	...	*	
36. maculata, *Mont.*	...	*	
37. Proctonotus mucroniferus, *A. and H.*	...	...	*
38. Alderia amphibia, *Allm.*	...	*	
39. Eubranchus tricolor, *For.*	...	...	*
40. Eolis papillosa, *Linn.*	*	*	*
41. Zetlandica, *For.*	*	...	*
42. rosea, *A. and H.*	*		
43. obtusalis, *A. and H.*	*		
44. angulata, *A. and H.*	*		
45. stipata, *A. and H.*	...	*	
46. nana, *A. and H.*	*		
47. aurantia, *A. and H.*	*		
48. concinna, *A. and H.*	*		
49. olivacea, *A. and H.*	*	...	*
50. Northumbrica, *A. and H.*	*		
51. viridis, *For.*	...	...	*
52. Hystrix, *A. and H.*	*		
53. vittata, *A. and H.*	*		
54. pallida, *A. and H.*	*	...	*
55. Farrani, *A. and H.*	...	...	*
56. violacea, *A. and H.*	*	...	*
57. foliata, *For.*	*		
58. cœrulea, *Mont.*	...	*	
59. alba, *A. and H.*	...	...	*
60. coronata, *For.*	*	*	*
61. pedata, *Mont.*	...	*	
62. Cuvieri, *John.*	*		
63. Drummondi, *Thom.*	...	...	*
64. curta, *A. and H.*	*		
65. rufibranchialis, *John.*	*		
66. pellucida, *A. and H.*	*		
67. gracilis, *A. and H.*	*		
68. longicornis, *Mont.*	...	*	
69. purpurascens, *Flem.*	*		
70. plumosa, *Flem.*	*		
71. minima, *For.*	*		
72. despecta, *John.*	*	...	*
73. Pterochilus pulcher	...	...	*
74. Calliopæa dendritica, *A. and H.*	...	*	
75. ? bifida, *Mont.*	...	*	*

In the division No. 1 (north and east) there are,—

Doridæ	16	
Tritoniadæ	30	
	—	46

No. 2 (south),—

Doridæ	14	
Tritoniadæ	15	
	—	29

No. 3 (west),—

Doridæ	22	
Tritoniadæ	20	
	—	42

The principal thing to be remarked in these catalogues is the deficiency of *Tritoniadæ* in the south and west compared with the north-eastern division. That this family, particularly the genus *Eolis*, is a northern form, will become still more apparent if we compare our native species with those of foreign countries. The whole number of foreign species described, as far as we have been able to ascertain, is

Doridæ	104	
Tritoniadæ	43	
	—	147

of these the genus *Doris* contains	88
Eolis	22

Comparing these with the number of British species of the two families,

Doridæ	29	Doris	18
Tritoniadæ	46	Eolis	33

and taking into account that a majority of the foreign species are from warmer climates than our own, we see that the *Doridæ* greatly predominate in the southern and tropical seas, and the *Tritoniadæ*, particularly the genus *Eolis*, in the northern. Some allowance however must be made for the great imperfection of our knowledge of foreign species, and the circumstance that the Dorides being the largest and most conspicuous animals of the class would be the first to be observed; but that this is not sufficient to account for the difference will be evident if we compare the *Nudibranchiata* of the Mediterranean with those of our own coast. The Mediterranean has been searched by many able naturalists, and its Fauna pretty accurately ascertained. A glance at its species of *Nudibranchiata* will at once show the predominance of the Dorides, their superiority in number as well as in size and brilliancy of colour over those of our northern climate. But if we look to their Eolides, we shall, on the contrary, find them few in number and small in size, and not at all to be compared with those of the British shores.

The embryology and development of the Nudibranchiate Mollusca have not until lately engaged much attention. M. Sars was the first to announce (in Wiegman's Archives for 1841) that these animals undergo a true metamorphosis, and that in their young state they are inclosed in a shell, a fact which your reporters have since had the opportunity of verifying in several of the genera. Dr. Grant had previously published, in the Edinburgh Journal of Science for 1827, an account of the development of several of the Mollusca, in which he pointed out the existence of vibratile cilia in the embryo, and their use as a means of locomotion on its exclusion from the egg; but he had failed to distinguish the peculiarities of the Nudibranchiate species, as he states that there is a remarkable similarity between them and the young of *Buccinum* and *Purpura*, species which do not undergo any metamorphosis.

The spawn of the Nudibranchiate Mollusca is deposited in the shape of a gelatinous band, always arranged in a more or less spiral form, and fastened to corallines and the under sides of stones by one of its edges. The ova are minute and very numerous, amounting in some species to several thousands. Before the period of exclusion, the young may be seen revolving on their own axis by means of vibratile cilia, and on escaping from the egg, they swim about freely in the water by the same means. The larva is extremely minute, and has more the appearance of a rotiferous animalcule than a Mollusk. It is inclosed in a transparent, calcareous, nautiloid shell, with an operculum. Its structure is very simple, showing no signs of the external organs that distinguish the future adult. The principal portion visible outside the shell is composed of two flat discs or lobes, fringed with long cilia, by the motion of which it swims freely through the water. These are often withdrawn into the shell, and the operculum is closed upon them when the animal is at rest. We have not yet been able to trace the animal further than the first stage of its development, and are therefore unable to say by what process it assumes the very different form of the adult state. We have succeeded in bringing out the larvæ of *Doris, Tritonia, Melibœa*, and *Eolis*, between all of which there is a very great resemblance. The embryology of the *Mollusca* has been so little investigated, that it would be difficult to point out the alliances that this mode of development appears to indicate. M. Van Beneden has shown the existence of a similar larva in *Aplysia*, and it is probable that *Bulla* and some others of the *Tectibranchiata* will be found to follow the same type. The majority of those *Gasteropoda* whose embryology is known do not undergo any metamorphosis. The ciliated discs observed in the young of *Buccinum* and *Purpura* after birth cannot be considered an exception, as they disappear almost immediately, and the shell and other organs with which the young animal is furnished on its exclusion from the egg are essentially the same that it retains to the latest period of its existence.

The anatomy of the *Doridæ* was carefully studied by Cuvier, and found by that distinguished naturalist to agree in all important characters with the true molluscan type.

The Eolidians, however, which comprise most of the *Tritoniadæ*, vary in this respect from the rest of the order. M. Milne-Edwards was the first to draw the attention of physiologists to the fact, and more recently M. de Quatrefages has investigated the subject with great elaboration.

In most of the Gasteropodous Mollusca the liver is largely developed, but in this division of the *Nudibranchiata* that organ entirely disappears from the abdomen. At the same time a system of vessels is found to exist in connection with the stomach, and branching into the dorsal papillæ, the interior of which is clothed with a coloured glandular substance, which probably acts the part of a liver and contributes to the digestive process. This system of vessels has been called gastro-vascular, and is stated to receive the more refined products of digestion immediately from the stomach. It is compared by M. Milne-Edwards and M. de Quatrefages to the circulatory system of the *Medusidæ* on the one hand, and of *Nymphon* and some of the *Annulosa* on the other. It appears, however, according to our observations, to be merely an appendage of the digestive system, while the vessels of the *Medusidæ* unite the two functions of digestion and circulation into one. The circulation of the blood is provided for in the Eolidians by a separate system of vessels, consisting of a heart and arteries; but according to M. de Quatrefages the veins disappear in his genus *Eolidina*, their place being occupied by lacunæ. The respiratory function resides chiefly in what are called the branchial papillæ. The skin, however, considerably assists in aërating the blood. This function is therefore more diffused than is usual in the *Gasteropoda*, in most of which respiration is provided for by highly developed branchiæ. In the typical *Doridæ* the branchial plumes are of a very elaborate character, but we may perceive in some of the thin-skinned genera of that family, as in *Polycera*, an indication, by the presence of vibratile cilia over other parts of the body, that the skin participates in the respiratory functions, as in *Eolis* and other of the *Tritoniadæ.*

These are some of the principal deviations from the normal character of the order, which have induced M. de Quatrefages to detach the genus *Eolis* and its allies from the order *Nudibranchiata*, and to place them in his new order *Phlebenterata*, in which they are associated with some Mollusca of very inferior organization, containing the genus *Acteon* of Oken (of which the *Aplysia viridis*, Mont. is the type), and some other genera still more simply organized. The point of agreement between these is stated to be the presence of a gastro-vascular system, but in the latter genera, which are united into a suborder (*Dermobranchiata*), this system appears to perform the three functions of digestion, circulation and respiration, which, indeed, is stated by M. de Quatrefages to constitute the dominant character of the order *Phlebenterata.* We think, however, that no satisfactory evidence has been adduced of such union of functions in any of the *Nudibranchiata*, and so far as we have examined the species our experience is against the supposition.

The senses are as highly developed in the *Nudibranchiata* as in any of the other gasteropodous Mollusks. The eye is furnished with a well-formed pigment-cup, a spherical lens, a cornea, and a general capsule. It is present in all the genera, but in *Doris* it can only be seen externally in young individuals; the thickening of the cloak obscuring it in the adult animals, and probably impeding the function. The auditory apparatus is composed of a small vesicle, containing concrete vibratile bodies. Touch is perceived by the whole surface of the body, but is most likely specialized in the labial tentacles, and taste may be inferred from the fleshy lining of the mouth. In a paper read before the last meeting of this Association, we gave reasons for supposing that the sense of smell resides in the dorsal tentacles. These organs have a much more elaborate structure in the *Nudibranchiata* than in any of the other Gasteropods, and approach so nearly in their lamellated structure to the olfactory apparatus of fishes, that we entertain little doubt of their performing the same function. The sense of smelling is therefore probably enjoyed by them in a higher degree than in any other of the *Gasteropoda.*

In both the great divisions of the order the senses are equally well developed, and we should instance this fact as a reason for keeping them united. In both the nervous systems are the same, as are also the generative organs; and in both too there is a considerable similarity in the respiratory organs, and perhaps when the circulatory systems are better understood, less deviation will be found to exist in them than is at present supposed. The relationship between the two divisions is also seen in the similarity of the spawn, and, what is still more striking, in the perfect similarity that exists in the larva state of each, and the consequent metamorphosis that both must undergo.

For these reasons we are disposed to adhere at present to the arrangement of Cuvier, though, from the discoveries that have been recently made in their anatomy, some alterations become necessary in the divisions of the order.

Researches on the Influence of Light on the Germination of Seeds and the Growth of Plants. By ROBERT HUNT, *Secretary to the Royal Cornwall Polytechnic Society.*

IN the course of these investigations many very curious, and in some cases apparently anomalous results have presented themselves, and tended greatly to increase the difficulties of the question. Experiments have been continued during the whole of the beautiful summer of 1844, and many are now in progress. It will be necessary to repeat these during another season; and I feel, therefore, under the circumstances of difficulty in which I am placed by the publication of very different results obtained on the other side of the Atlantic, compelled to defer until the next meeting of the Association anything like a regular report. I shall, however, place upon record a few of the experiments, as they may serve to direct attention to an inquiry, in itself of the greatest interest, and leading to the development of some of the most important problems connected with the dependence of organization and life on the solar influences.

It must be understood, unless it is distinctly stated to the contrary, that the arrangements have been the same in principle, although on a much more extended scale, as those which I have described in the report made to the Association in 1842.

I have used different absorptive media, and by a most careful prismatic analysis of the rays by which they have been permeated, I have ascertained with considerable correctness the condition of the rays which have been in active operation. Not only have I examined the luminous spectrum produced after the rays have undergone absorption, but I have ascertained the relative quantity of the active chemical principle (ACTINISM) which has passed through the coloured glasses and fluids, by obtaining in every case several spectra impressed upon photographic papers.

I have found, that by using different thicknesses of glass, by superposing glasses of different tints, and by varying the depth of colour in my solutions, I have been enabled to procure with tolerable purity well-insulated rays.

As in the former report I have spoken of the colours of the glasses and fluids as bearing some relation to the unabsorbed rays, I shall continue to do so. It will not be improper to state that the following arrangement may be regarded as fairly representing all the conditions of each experiment. When I speak of a BLUE MEDIUM, it will indicate the presence of the most *chemically active rays.*

A RED MEDIUM the presence of the most calorific rays.

A YELLOW MEDIUM the greatest amount of light with the least quantity of heat and chemical power.

A GREEN MEDIUM will indicate in most cases, light and chemical power nearly balanced.

On the 20th of March I sowed seeds of the sweet-scented pea in the open ground, and in a box divided in partitions, so that each division was under the influence of that light only which had permeated the media by which it was covered. Under the influence of the blue and red media the seed germinated six days before those sown in the open ground. The seed under the yellow and green media germinated, and threw up their leaves at the same time as those which had been placed under perfectly natural circumstances. These pea plants were all of them allowed to grow until the 18th of April, when they were drawn from the soil; their roots cut off, and the plants, twelve from each compartment, carefully weighed. Their respective weights were as follows:—

Twelve plants grown under blue media	$195\frac{6}{10}$ grs.
Twelve plants grown under red media	276 grs.
Twelve plants grown under green media	$243\frac{5}{10}$ grs.
Twelve plants grown under yellow media	264 grs.

It is important to notice, that all the plants which had grown under the blue medium were of a fine fresh and healthy *green colour.* Those which had grown under the influence of the yellow had *white stalks*, all the lower leaves were of a very delicate green, whilst the upper ones were yellow. An opening in the upper cover of the box admitted a little white light from the northern sky, and under its influence the leaves above the yellow ones became green. These specimens were carefully dried in the sunshine, by which they lost in weight respectively as follows:—

Those grown under the blue media	178·9 grs. or 91·4 per cent.
Those grown under the red media	252·2 grs. or 91·3 per cent.
Those grown under the green media	219·4 grs. or 90·1 per cent.
Those grown under the yellow media	239·1 grs. or 90·6 per cent.

When, however, these were placed on a stove, and still higher dried, the results were more equalized;

The plants under the blue losing	92·84 per cent.
The plants under the red losing	92·75 per cent.
The plants under the green losing	92·40 per cent.
The plants under the yellow losing	92·31 per cent.

From the above results it would appear that the rays which permeated the green and yellow media, had the property of occasioning the secretion of larger quantities of woody fibre than the other rays, the quantities of water or volatile matter being greater in the plants grown under the blue and red;

Those under the blue leaving	7·16 per cent. of woody fibre.
Those under the red leaving	7·25 per cent. of woody fibre.
Those under the green leaving	7·60 per cent. of woody fibre.
Those under the yellow leaving	7·69 per cent. of woody fibre.

These facts certainly appear to strengthen the opinion which has been expressed by Dr. Daubeny and others, that the decomposition of carbonic acid in plants is effected by the yellow or luminous ray. I have on two previous occasions stated the blue rays of the spectrum to be the most active in effecting this decomposition, and in all my experiments made with a particular view to the examination of this question, I have found the liberation of oxygen more abundant in tubes which were placed at the blue end of the spectrum; these tubes being filled with water holding carbonic acid in solution, and some small leaves plucked from my garden. I have only stated the results of one set of my experiments in which the balance was used to test them. It is due to those holding a different view from myself, to state that three sets of experiments gave nearly similar results. At the same time, as these experiments would appear to show that yellow light is not injurious to the growth of young plants, it must be most distinctly understood that the contrary has been, in every instance, proved to be the case. The plants have always been more or less etiolated, whereas those which have grown under the influence of the blue rays, have always presented lively and beautifully green leaves. I cannot, therefore, admit at present that the formation of chlorophylle is due to the luminous rays.

April 19th.—Seeds of the sweet-scented-pea and mignonette were planted in the partitions of boxes, arranged as above. On the 29th the seeds under the blue and red media had thrown up leaves in abundance; those under the blue being marked by their very healthful character. A few dwarfed and miserably pale plants had appeared under the green media, but not one under the yellow media. After a few days the peas under the yellow began to germinate, and the plants presented the same aspect as I have described. But although the most careful attention was given I could not succeed in producing the germination of mignonette under the influence of those rays which have permeated the bichromate of potash in solution.

In my first published experiments, I stated that the luminous rays acted most injuriously upon germination and prevented the growth of young plants. Every experiment has tended to confirm my first statement, and however much uncertainty—and I have not endeavoured to hide this—there may be about some other phænomena of vegetation, there is not any on this point. *Light prevents healthful germination and is injurious to the growth of the young plant.* A number of fine young Pansies were placed in the most favourable circumstances under different absorptive media, on May 19th. On the 1st of June the Panseys under the yellow media were found to be dead, whilst all the others were growing well. When planted these plants all had small flower-buds, but with the exception of the plants under intense red media I could not get a flower to form upon any. Several of the ten-week stocks were removed from the garden in the most healthy conditions when of about a fortnight's growth; the stocks exposed in the yellow light died in ten days. With these plants I succeeded in obtaining flowers both under the influence of the blue and the red media. I reserve the statement of many other experiments to a future occasion. In justice, however, to myself, I am bound to state that I have repeated Dr. Gardner's experiments on the production of chlorophylle without success.

Postscript, Nov. 20.—On my return to Falmouth after the York meeting, I found all the peas and mignonette dead, except under the red fluid. This mignonette was very healthy, abundant and in full flower, in which state it continues to this time. Would not this point to the use of red media for preserving delicate plants in the winter season?

Report of a Committee, consisting of Sir JOHN HERSCHEL, Mr. WHEWELL, *and* Mr. BAILY *(deceased), appointed by the British Association in* 1840, *for revising the Nomenclature of the Stars.*

THE obvious importance and necessity of arriving at some definite practical conclusion which might be satisfactorily acted upon in assigning a uniform system of constellations, letters, numbers and names to the stars in each and all of the three great Catalogues now in course of preparation under the auspices of this Association, viz. the "British Association Catalogue," the Southern Catalogue of Lacaille and the extensive Catalogue of the Histoire Céleste, has caused your Committee to assign this particular object as the present term and scope of their labours, the Catalogues in question being fully prepared for publication, and being actually in course of printing. The great extent and high authority of these Catalogues,—their appearance all at one epoch,—their preparation on a uniform system digested and arranged by the master-mind of our late lamented colleague,—and the use of the same nomenclature throughout all the three,—can hardly fail to give that nomenclature universal currency in every observatory for a very long time to come, and to do away at once and for ever with the uncertainty and confusion which has so long and so unhappily prevailed in this respect.

In resting at this point, therefore, your Committee consider that a great practical benefit will have been conferred on astronomy. And in resolving on this course they have necessarily abandoned (not without much discussion, extensive foreign correspondence, interchange of opinion with British astronomers, and many partial modifications of the design,) the idea which they had originally entertained of a total remodelling of the southern constellations and redistribution of them into groups more easily recognizable than those which have obtained currency.

Your Committee, however, are desirous to be distinctly understood that for certain astronomical purposes, although not for those to which catalogues of stars arranged in order of right ascension are especially applicable, such a remodelling, not only of the southern constellations but of those in both hemispheres, is both desirable and necessary. Neither are the means of putting such a project in execution wanting, as heretofore. The celestial charts of Messrs. Argelander, which have arrived in this country and been consulted by your Committee, would alone furnish data for such an undertaking. To their general accuracy in respect of the magnitudes of the stars, as far exceeding that of any other publication which has come to our knowledge*, we are prepared to testify—one of our number (Sir J. Herschel) having (since the appointment of this Committee and in ignorance of M. Argelander's labours) carried out over the whole of the northern hemisphere, and that part of the southern which lies between the Equator and the tropic of Capricorn, a survey for the express purpose (in continuation of a similar survey previously begun and completed by him for the southern constellations), in which the whole surface of the heavens has been divided into triangles, and each triangle examined seriatim down to stars of the sixth magnitude.

Nevertheless your Committee do not propose to extend their labours at present to such a general remodelling. A resting-point has been attained, and one of great value, even considered as a step to such an ulterior design, as will be found explained in a statement, embodying the nature of the conclusions arrived at by the corrections effected and the alterations which it has been found indispensable to make, drawn up by our late lamented colleague Mr. Baily, and forming part of his preface to the Catalogue of the British Association, which we append to this report.

It ought to be mentioned, that the whole of the labour of revising and correcting the nomenclature of the constellations visible in Europe, constituting by far the most difficult and delicate part of the task undertaken, and involving the necessity of a hardly credible amount of patient and persevering research, has been executed by him, together with the very considerable additional work of applying the general principles agreed on for the southern circumpolar regions to the stars occurring in all the catalogues, and disposing finally of the many difficulties which arose in so doing.

No part of the remainder of the original grant of the Association (amounting to £32 0*s.* 6*d.*) has been actually disbursed during the current year by the Committee, but liabilities have been incurred by the purchase of Messrs. Argelander's and Schwinke's maps, and for some items of less importance, which it has not been possible finally to discharge or even precisely to ascertain owing to the recent melancholy event above alluded to, which will render it necessary to continue to regard the grant in question disposable for those purposes, though in other respects this report may be considered as final.

(Signed on the part of the Committee) J. F. W. HERSCHEL.

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* The charts of M. Schwinke which, at the date of our last report were understood to be either published or in immediate course of publication, were ordered for the Committee, but have not yet come to hand. The examination of M. Argelander's however had proved so satisfactory, as confirmatory of their views on a great many points, that it has not been considered expedient to defer coming to a final conclusion (which would have retarded indefinitely the printing of the Catalogues) for the arrival of the others.

APPENDIX.

Revision of the Constellations[*].

The advantage and importance of having the boundaries of the constellations of the stars distinctly and properly defined on our maps and globes, must be evident to every one that has occasion not only to refer to so useful and convenient an auxiliary to the practical astronomer, but also to consult a catalogue of stars. For unless due attention is paid to some clear and well-organized plan of arrangement, and to some regular method of drawing the lines that constitute the limits of the constellations, much confusion and intricacy soon enters into the system, and not only does the whole become an unintelligible mass of intersecting and undefinable boundaries, but the nomenclature of the catalogues also becomes sadly deranged. This is no ideal annoyance; for the present state of all our modern maps and globes bears evident proofs of the existence of the evil to which I have here alluded; and the catalogues likewise partake largely of this confusion. But the time has arrived when this inconvenience, now become so troublesome and perplexing, can be no longer tolerated. The extended state of the present catalogue (in which there are a number of additional stars selected from various works, differing very essentially in the nomenclature of the stars which they contain) requires that every star thus introduced should be located on maps in which the boundaries of the constellations are constructed and drawn (or assumed to be constructed and drawn) upon some definite and systematic plan; so that the name of the constellation, to which the star may be thus found to belong, should be correctly affixed thereto, and thus show at once its true and accurate locality in the heavens. This can only now be done by a general revision of the whole system.

Ptolemy drew his *figures* on the globe in such a manner that the stars should occupy the positions that he has designated in the descriptions of them in his catalogue: and the boundary of each figure thus drawn was, in fact, the limit of the *constellation* intended to be represented. For, when he observed any stars that were beyond the outline of his figures, he denominated them ἀμόρφωτοι, *unformed*; and this method was long followed by his successors. But, in the time of Tycho Brahé, this plan was in some measure departed from, and a more comprehensive extension of the original limits adopted, by including the unformed stars within the boundaries of one or other of the contiguous constellations; so that all the constellations abutted against one another, and the whole of the heavens was thus occupied by one portion or another of some known constellation; the *figures* remaining the same. Some confusion however soon crept into this arrangement: for it appears that one of Ptolemy's *unformed* stars in *Libra* (543 of my catalogue of Ptolemy) was very justly placed by Tycho within the boundary of the same constellation; in which arrangement he has been followed by Flamsteed, who designates it 20 *Libræ*. But Bayer has unfortunately placed it in the constellation *Scorpio*, an arrangement which has been adopted by Hevelius, Lacaille and others. Thus some confusion in this part of the boundaries of these two constellations has been introduced, and which continues to the present day. I have adopted Tycho's arrangement, and made the discordant catalogues agree therewith; as it cannot be tolerated at the present day that this confusion should be perpetuated, or even now exist. When Hevelius formed his catalogue, he observed many stars, in the large spaces between Ptolemy's figures, that had not been previously noticed; and in

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[*] This section forms the substance of a Paper that was read at a meeting of the Royal Astronomical Society, on May 12, 1843.

these spaces he introduced new figures, or constellations, many of which are still retained. But the greatest innovator on this system was Bode, who although no great observer himself, has, in his catalogue and in his maps, filled the heavens with a host of new figures and constellations that were by no means requisite, and that tend only to annoy and confuse, without presenting one single advantage.

In these remarks I have reference only to the constellations in the northern hemisphere; or, at least, to those constellations only that are visible in the northern latitudes, which, of course, include many of the southern stars. When the southern ocean however was visited by European navigators in the sixteenth century, a map of the portion of the heavens, there visible and not hitherto described, became requisite and was soon formed: but it was not till the time of Halley that any catalogue or map of the southern constellations could be depended upon. The constellations that were adopted or introduced on this occasion were in some measure altered and increased in the last century by Lacaille, who has, at the same time, encroached on the boundaries of the former constellations, which, although situate to the southward, had been tolerably well defined and agreed upon by the northern astronomers; whereby he has created much confusion and ambiguity. For this reason, and in order to remove such confusion of terms and identity, it has been considered requisite to revise also the constellations and nomenclature introduced by Lacaille. I shall however again advert to this subject when I have gone through the proposed revision of the northern constellations.

When Hevelius formed his catalogue of stars, he at the same time constructed maps of the constellations, in which they were to be respectively placed. By this method he in some measure preserved an uniformity in his classifications and arrangements, and obviated any considerable distortion of the boundaries of the constellations, having himself defined the limits. But Flamsteed did not possess this advantage, since his maps were not constructed till long after his catalogue had been formed, and indeed not till many years after his decease: and as Hevelius's maps were not published till after Flamsteed had commenced his observations with the mural quadrant, the 'Uranometria' of Bayer was the only authority to which he could refer even for an approximate classification of any new stars that he might observe. This however appears to have been often done either without due consideration and attention, or from ignorance of the true limits; and the name of a constellation was frequently written down, in the margin of the observation-book, as that which, *at the time of observation*, Flamsteed supposed to be the true constellation under review; but which afterwards, when the observations came to be reduced and arranged, have been found to be incorrect. An inspection of Flamsteed's manuscript books, at the Royal Observatory at Greenwich, and indeed the second volume of his 'Historia Cœlestis,' will fully confirm this remark. The consequence has been that several of the stars in his catalogue have been inadvertently arranged and classed under erroneous constellations: and our modern map-makers (instead of correcting these obvious errors in due time, and in a proper manner, or of laying down any general principle, on which the boundaries might be constructed and drawn, in all cases of new discoveries) have suffered the evil not only to continue, but to increase to such a degree by subsequent innovations, that the celestial maps have at length become a system of derangement and confusion. For, a practice seems to have been adopted that whenever a modern astronomer has, in his catalogue, inadvertently introduced a star which he has designated by an erroneous constellation, the map-maker, or globe-maker (probably through ignorance), immediately extends the circuit of the constellation so as to embrace the star within its limits; although in so doing he causes the most inconvenient and absurd distortion of the boundary lines, and, in some cases, actually includes thereby stars that ought not to have been disturbed; which consequently renders the map, or the globe, a mass of confusion and intricacy, and totally unfit for accurate reference. An inspection of most of the modern celestial maps or globes will fully confirm this remark.

Before a catalogue of any considerable extent, containing new stars, is finally arranged as to its nomenclature, a specimen map of the constellations, or at least their general outlines or boundaries, ought to be laid down upon some uniform and acknowledged system, for the guidance of the astronomer. The plan which was pursued by Ptolemy, and which with some slight alterations has been continued down to the present time, may serve as a basis for modern guidance and improvements. Its antiquity, and the numerous references which have always been, and still are, constantly, made to it, render it now difficult (even if it were desirable) to make any considerable deviation from a system which is associated with so many scientific, historical, and mythological recollections. But whatever plan be adopted, it ought to be preserved with some degree of uniformity and regularity: so that if an author has inadvertently designated a star by a wrong constellation, the name in the catalogue should be amended, rather than the boundary of the constellation distorted. This however will occasionally admit of some laxity; for, if such star should happen to be near the confines of a constellation, a *slight* variation in the curvature of the boundary may be justly allowed in the case of a well-recognised star, more especially as the precise limits are in some measure arbitrary. But where a star in any catalogue is designated by the name or title of a constellation, to which it manifestly does not belong, and has been inadvertently recorded and arranged as one of the stars in such constellation, the only proper mode of correcting the error is to alter its name and character in the catalogue, and thus restore it to its proper designation and position.

As an example of the confusion which is created by such misnomers, I need only adduce the case of two stars in Flamsteed's catalogue; one of these is called 44 *Lyncis*, but whose position is in the middle of *Ursa Major*, and was so located by Ptolemy; and the other is called 19 *Ursæ Majoris*, which evidently belongs to *Lynx*. Now the map-maker, in order to comprise these stars within the limits of the constellations in which Flamsteed has thus inadvertently and erroneously located them, has extended the boundaries of each of these constellations in such a confused and intersecting manner that the limits are scarcely intelligible. The proper mode would have been to alter the nomenclature, at once, in the catalogue; and thus prevent the perpetuity of the error. Another example (still more remarkable) occurs in the star 13 *Argus* in Flamsteed's catalogue; a star that is in fact situate in the constellation *Canis Minor*, which lies to the north of the *intermediate* constellation *Monoceros*: and the map-maker, in order to include this distant star within the limits of *Argo*, has in a similar manner traced a double line directly through the body of *Monoceros*, which thus appears like two distinct constellations. Many other similar examples of distortion might be adduced, but it is needless to multiply proofs of such evident absurdities, which need only be seen to be duly estimated and repudiated.

Cases of another kind occur where the constellation is improperly and unnecessarily extended, although there may not be any intersection of the boundary lines: such as that which may be seen in Flamsteed's catalogue of stars, in the constellation *Crater*, where many of the stars there introduced do not fall within the limits of the figure drawn by Bayer; nor is Flamsteed's extension of the boundaries warranted by Ptolemy's description of the position of the stars in that constellation[*].

Much confusion has also arisen from inattention to a regular classification and arrangement of certain clusters of stars that lie near the adjoining confines of two contiguous constellations; such as the cluster of stars about the head of *Serpens*, which are strangely intermixed with the stars that are considered to be in the arm of *Hercules*: and many similar cases may be seen in *Monoceros* and *Hydra*, *Draco* and *Cepheus*, *Auriga* and *Camelopardus*, *Libra* and *Hydra*, *Hercules* and *Ophiuchus*, *Vulpecula* and *Cygnus*, &c.

But the most striking proof of the inattention of map- and globe-makers to accuracy of arrangement, occurs in the cases where the author of the catalogue has placed the same star in two distinct constellations, and where unfortunately (in constructing the map) the erroneous one has been selected for its location. A singular case of this kind occurs with Flamsteed's 25 and 27 *Aquarii*, which are the same stars as 6 and 11 *Pegasi*. The map-maker has correctly placed the stars in the head of *Aquarius*, as drawn on the map; but then, as if doubtful of such a step, or desirous of preserving the double interpretation, has extended the boundary line of *Pegasus* so as to embrace it within the limits of that constellation.

Cases of such double insertions in a catalogue are not to be wondered at in the early state of the science, where minute accuracy was not always attainable, nor the error always discoverable on account of the mode of classification; and we accordingly meet with a few of such cases in the catalogues of Ptolemy and others. But in more modern times the error has arisen principally, if not solely, from the method of arranging the stars, in a catalogue, under distinct and separate constellations, whereby the similarity of position is not readily discovered; and this will account for the synonyms that occur in the catalogues of Flamsteed and Hevelius: but when discovered they ought to be at once corrected, and not suffered to remain a perpetual blot in the catalogue. The modern mode, however, of arranging the *whole* of the stars in a catalogue, according to the order of their right ascension, without any regard to the order of the constellations in which they may be placed, prevents the occurrence of a similar inconvenience in future.

But a like source of error arises, and frequently causes doubt and difficulty to the map-maker, and even to the astronomer, when the authors of two different catalogues vary in their decision as to the constellation in which a star should be located. Numerous instances of this kind may be seen in comparing the catalogues of Hevelius and Flamsteed, or either of these with the catalogues of Piazzi or Taylor: which confusion has arisen from a want of a system of well-defined and acknowledged boundaries to the respective constellations, whereby the astronomer may know when he is correct in locating the observed stars. Let any one examine the stars in Hevelius's first constellation (*Andromeda*), and he will there find that Flamsteed has placed some of them in *Pegasus*, one in *Perseus*, and one in *Lacerta*; whilst Piazzi places one of them in *Cassiopea*. Those only who have to make frequent references to the class of smaller stars, and are desirous of identifying them, and of comparing the results of different observers, can justly appreciate the labour and inconvenience that occurs from such a confused state of location. And with respect to the map-maker, it is a forlorn hope to expect from him anything like regularity, uniformity, clearness or precision so long as he continues the present system of circumscribing every star with the boundary line of the constella-

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[*] An exception, perhaps, might here be made to Flamsteed's 11 *Crateris*, and which Bayer has designated by the letter β: a star which Ptolemy places in *Hydra*, at the same time however describing it as *μετὰ τὴν βάσιν τοῦ κρατῆρος*. I have followed Bayer and Flamsteed.

tions to which the author of the catalogue, in which it is found, considers it to belong, and rejects every attempt at improvement.

On the maps published by the executors of Flamsteed, there are not any boundaries surrounding the figures that are there drawn: for, all the stars in Flamsteed's catalogue are placed in their true positions (as to right ascension and declination) as given in the British Catalogue, without any boundary lines; and those who consult the maps are at liberty to draw the boundaries in such manner as they may think most proper. It is the catalogue which is in error, and not the maps; and it is very probable that the editors were aware of this circumstance, having found out the mistake when it was too late to mend it.

Bode appears to have been the first that drew boundary lines to the constellations; and in so doing, instead of correcting the catalogue and preserving an uniform system of drawing his lines in a simple and regular manner between contiguous constellations, whereby the contour was distorted as little as possible, he introduced the practice (above mentioned, and which has been implicitly followed by most of the English map- and globe-makers) of *hooking* within such limits all the stars that Flamsteed or any subsequent astronomer had inadvertently designated by a wrong constellation; thus disfiguring and distorting the boundaries and rendering them very intricate, perplexing, and annoying. In his large set of celestial maps, however, which he published about twenty years afterwards, he became sensible of his error, and very prudently discontinued this absurd practice, and confined his boundaries to their proper restriction. But the English map- and globe-makers, instead of following this laudable example, have not only continued the evil, but have carried the practice to such an enormous and ludicrous extent that the modern celestial charts and globes at the present day exhibit a complete mass of intersecting and conflicting lines, utterly subversive of the object and design of such a divisional arrangement of the heavens. Harding, in his Celestial Atlas, has avoided this confusion: and so likewise has Argelander in his recent 'Uranometria.' So that there is probably now some prospect of our being able to obtain, in this country, celestial maps and globes freed from all the mischievous confusion with which they are encumbered: and if the globes (and also the maps) were confined to such stars only as are visible to the naked eye, their utility and convenience for an ocular view of the heavens would be much improved*.

In order that our catalogues and our maps (or globes) should speak the same language, and that they should at the same time be clear and intelligible to those who consult them for the purpose of identifying the stars in the heavens, it is requisite that the nomenclature of the stars, or, in other words, the boundaries of the constellations, should be placed on a more uniform, regular, and well-defined plan: but, in making this necessary reform, regard must be had (especially in the northern hemisphere) to long-established names and authorities, which by their antiquity and constant use have acquired full possession of the public opinion and favour. Now, it fortunately happens that very material improvements may be made in the present mode of delineating the boundaries of these constellations, without encroaching at all on any of the ancient arrangements, and without much alteration in those of more modern date. All that is required will be the correction of some of those manifest errors which have been caused principally by following too closely and implicitly the arrangement and classification of the stars in the constellations in Flamsteed's catalogue; and which has opened the door to further encroachments by his successors.

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* Argelander's 'Uranometria' is an excellent pattern for such a system of map-making.

I have alluded here to the correction of Flamsteed's catalogue only, not however as being the only one (or even the most discordant) that requires reform, since similar anomalies, and equal in amount, are to be found in the catalogues of Hevelius, Piazzi, Taylor, and perhaps some others; but because it is the only one in these latter days (if we except Hevelius's, which is not very frequently referred to) in which the stars are quoted and known by the numerical order and position in which they stand in the respective constellations; those of other astronomers being always designated by the order of their right ascension. And as all our map- and globe-makers fill up the boundaries of the constellations with Flamsteed's *numbers* as they find them in his catalogue, whether properly located or not, it is requisite in the first instance to place those stars in their proper positions. The method which I propose for carrying this object into execution, and for reforming the boundary lines, is the following: viz.

1°. That Ptolemy's constellations be preserved, and form the basis of the construction and arrangement of the constellations in the northern hemisphere.

2°. That nine of the constellations, adopted by Hevelius, be retained; but that no others be introduced in the northern hemisphere. These nine constellations are *Camelopardus, Canes Venatici, Coma Berenices, Lacerta, Leo Minor, Lynx, Monoceros, Sextant*, and *Vulpecula*; which, having been adopted also by Flamsteed, are still referred to at the present day, and consequently should be retained. But the rest, as well as all the other constellations introduced by Bartsch, Bode, Hell, Kirch, Lalande, Lemonnier, and Poczubut, having fallen into general disuse, need not be revived or continued. Even those which are retained as above mentioned might be diminished with much benefit to the practical branch of astronomy: for this modern propensity to multiply the number of constellations has led to great confusion and annoyance (especially where they interlace with each other) without being attended with a single advantage.

3°. That Ptolemy's figures be attended to, so that the drawings (if any) should embrace all the stars mentioned by him, and within their true outlines. *Libra* perhaps may be an exception to this rule, as this constellation has been introduced instead of the claws of *Scorpio* adopted by Ptolemy. There are also four stars in Ptolemy's catalogue that are common to two adjoining constellations: namely Flamsteed's 52 *Bootis*, which is common to *Hercules*; 112 *Tauri*, which is common to *Auriga*; 79 *Aquarii*, which is common to *Piscis Australis*; and 21 *Andromedæ*, which is common to *Pegasus*.

4°. That if Bayer or Flamsteed has introduced any star from another constellation that would distort the correct drawing, it must be named, in the catalogue, after the constellation to which it correctly belongs, and its pseudonym must be discontinued. In other words, the catalogue must be corrected, but not the boundaries of the constellations distorted. Thus, Flamsteed has, after the example of Ptolemy, correctly placed 51 and 54 *Andromedæ* in the right foot of that figure: but Bayer, inattentive to Ptolemy's description, erroneously makes these two stars form part of the sword of *Perseus*; and his mode of lettering those constellations is consequently inaccurate. Again, Ptolemy's 13 *Arietis*, which is distinctly described by him as being "in the extremity of the hind foot," is erroneously placed by Flamsteed in *Cetus* and is 87 *Ceti* in his catalogue; although it appears that both he and Halley, at one time, maintained the contrary*; and that Halley indeed inserted it in *Aries*, in his catalogue (1712). The proper mode of correcting such errors is to return to the original authority; a method which I have here adopted.

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* See my Account of the Rev. John Flamsteed, page 287.

5°. That the errors of Bayer or Flamsteed being thus rectified, and the figures of the constellations introduced by Hevelius being properly drawn (if requisite) within the intermediate spaces, the boundaries of the constellations, thus decided on, be carefully drawn and laid down agreeably to some systematic plan, which may thus serve as the perpetual limits of the constellations: and that no distortion of the outlines or boundaries of any of these constellations, in the northern hemisphere, be permitted in consequence of the mistakes of any subsequent astronomers in arranging their stars under improper divisions of the heavens.

6°. That as all Flamsteed's stars are designated by the numerical order in which they stand in the constellation, and as these numbers are in most cases well known and recognised, it is desirable to preserve his stars within the boundaries of their respective constellations, wherever it can be conveniently done. But, in the case of synonymous stars (amounting to 22) this is evidently impossible; and there are also several other cases, which have been already alluded to (amounting to 66, of which 19 belong to *Crater*), where it is impracticable, consistently with the rules here proposed[*]. These anomalous stars must be corrected in the catalogue, and there located in their proper constellations; which will thus in future be a guide to the globe-makers.

7°. That as all the stars in the catalogue of Piazzi are designated and always quoted by their *number* in the *hour* of right ascension, and those of Taylor and others, by their *ordinal number*, it is not so requisite to pay special attention to inscribing such stars within the boundaries of the constellations to which they are assumed to belong; and which will frequently be found to be discordant: still, that if any of these stars lie near to the boundaries so assumed, a slight detour be allowed in the drawing.

Such is the plan which I have pursued in the present arrangement of the stars in the northern constellations; and which I propose also to adopt in the classification of the stars deduced from the observations recorded in the 'Histoire Céleste.' I shall now proceed to state the several alterations that have been proposed by Sir John Herschel for amending the boundaries and nomenclature of the southern constellations. But, as I cannot add to the clearness and precision with which he has treated this subject, I shall here subjoin his statement in his own words.

" The idea, originally proposed of entirely re-modelling the southern constellations[†], has (after very mature consideration and much discussion, and after consulting the opinions of some of the most eminent continental astronomers, which have been found very adverse to the idea of so decided a change) been laid aside; at least in so far as regards the present undertaking. It is conceived however that if the nomenclature of the constellations, generally, be ever destined to undergo a systematic change at all (and many rea-

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[*] The following is a statement of the 66 stars in Flamsteed's catalogue, which I have assumed to be incorrectly arranged: viz. 13 *Argus* belongs to Canis Minor; 33, 34, 35 *Camelopardi* belong to Auriga; 50 *Camelopardi* belongs to Lynx; 85, 87 *Ceti* belong to Aries; 1, 2, 3, 4, 5, 6, 8, 9, 10, 17, 18, 19, 20, 22, 23, 25, 26, 28, 29 *Crateris* belong to Hydra; 3 *Cygni* belongs to Vulpecula; 30 *Draconis* belongs to Cepheus; 3 *Herculis* belongs to Serpens; 66 *Hercules* belongs to Ophiuchus; 1, 2, 3, 4, 5 *Leonis Minoris* belong to Lynx; 6, 41, 49 *Leonis Minoris* belong to Leo; 25 *Leonis Minoris* belongs to Ursa Major; 37, 39, 44 *Lyncis* belong to Ursa Major; 30, 31 *Monocerotis* belong to Hydra; 32, 33, 34 *Ophiuchi* belong to Hercules; 47 *Ophiuchi* belongs to Serpens; 23 *Piscium* belongs to Pegasus; 1 *Sagittæ* belongs to Vulpecula; 2 *Sagittarii* belongs to Ophiuchus; 24, 28, 29, 30, 31, 32, 33 *Scorpii* belong to Ophiuchus; 48 *Serpentis* belongs to Hercules; 10, 11 *Sextantis* belong to Leo; 16 *Trianguli* belongs to Aries; 10, 19 *Ursæ Majoris* belong to Lynx; 46 *Ursæ Majoris* belongs to Leo Minor; 101 *Virginis* belongs to Bootes.

[†] By Sir John Herschel himself, as stated in his Paper inserted in vol. xii. of the Memoirs of the Roy. Ast. Society.—F. B.

sons may be adduced for considering such a change desirable) the first and most important step towards it will be found in the present work itself, and in the catalogues, now publishing simultaneously with it on the same system of nomenclature*, which clear the ground of all existing confusion; and by assembling into one distinct view, and under names and numbers at least definite and recognised, all the individuals of which the new groups must be composed, render it easy at any future time to pass, by a single table of synonyms and by one decided step, from one to the other system, whenever the convenience and consent of astronomers may dictate the propriety of a change. Such views, if entertained, would render the nomenclature of the present catalogues so far provisional that a more rational and convenient system of groups (confined not to the southern hemisphere, but extending over both) may yet be contemplated by astronomers. Nevertheless, so long as the ancient system is at all retained, a general and scrupulous adherence to the nomenclature here adopted is most earnestly recommended to the astronomical world, as the only mode of escape from a state of confusion at present quite intolerable. As regards the southern constellations, the following are the principles proposed to be adhered to: viz.

"1°. That all the constellations adopted by Lacaille be retained, and his arrangement of the stars preserved; subject however to certain alterations hereafter specified.

"2°. That all the stars, having a doubtful location, such as those which Lacaille (after the manner of Ptolemy) has considered as ἀμόρφωτοι (unformed), be included within the boundaries of either one or other of the contiguous constellations, so as to preserve a regularity of outline.

"3°. That all the rest of Lacaille's stars be placed within the boundaries laid down by him, with the following exceptions: first, a few stars which are located too far from the border of the constellations in which they are registered, to admit of an uniform contour of the lines; secondly, such stars as have been previously observed by Ptolemy or Flamsteed, and by them located in other constellations, or which interlace and are confusedly mixed with such previously observed stars†; thirdly, the six stars that are placed by Lacaille in the end of the spear of *Indus*, but which are now assumed to form part of the constellation *Pavo*, in order to render the contour of these two constellations less circuitous.

"4°. That the Greek letters, selected by Lacaille, be adopted in preference to those introduced by Bayer in the southern constellations; but that they be retained only as far as stars of the 5th magnitude inclusive. That no Roman letters be used, except in the subdivisions of Argo, subsequently mentioned.

"5°. That Argo be divided into four separate constellations, as partly contemplated by Lacaille; retaining his designations of *Carina*, *Puppis* and *Vela*; and substituting the term *Malus* for *Pixis Nautica*, since it contains four of Ptolemy's stars that are placed by him in the *mast* of the ship.

"6°. That the original constellation *Argo*, on account of its great magnitude and the subdivisions here proposed, be carefully revised in respect of

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* Sir John Herschel here alludes to Lacaille's *new* catalogue of 9766 southern stars, and to the catalogue of upwards of 48,000 stars, deduced from the 'Histoire Céleste,' both of which are now printing at the expense of Government.—F. B.

† "A single exception to this rule occurs in the case of the last star in the constellation *Piscis Australis*, in Ptolemy's catalogue, which Bayer has denoted by the letter κ, and which is presumed to be the same as that which has been designated by Lacaille as γ *Gruis*. As there is some ambiguity however in the position of this star in Bayer's map, it is here assumed (like some other stars already mentioned) as common to both constellations, in order to adjust this discordance; and, in the present catalogue, Lacaille's designation of γ *Gruis* is retained, on account of its forming the principal object in the head of that constellation."

lettering, in the following manner: first, in order to preserve the present nomenclature of the principal stars, all the stars in *Argo* (that is, in the general constellation, regarded as including the subdivisions above mentioned) indicated by Greek letters, by Lacaille, to be retained, with their present lettering, under the general name *Argo*: secondly, all the remaining stars, to be designated by that portion of the ship in which they occur, such as *Carina, Puppis, Vela,* and *Malus,* and to be indicated by Roman letters, as far as the 5th magnitude inclusive. And no two distant stars, in the same subdivision, to be indicated by the same letter; but, in cases of conflict, the greater magnitude is to be preferred; and, when they are equal, the preceding star to be fixed upon.

"7°. That the constellations, which Lacaille has designated by *two* words, be expressed by only *one* of such words. Thus, it is proposed that the several constellations, indicated by Lacaille as *Apparatus Sculptoris, Mons Mensæ, Cælum Scalptorium, Equuleus Pictorius, Piscis Volans* and *Antlia Pneumatica,* be called by the respective titles of *Sculptor, Mensa, Cælum, Pictor, Volans,* and *Antlia*; contractions which have on some occasions been partially used by Lacaille himself, and are very convenient in a registry of stars."

Such is the plan proposed by Sir John Herschel for a better arrangement of the stars in the southern hemisphere: and, agreeing fully in the principles here laid down, I have not hesitated in adopting them in the construction of the present catalogue, and in the classification of the stars inserted therein.

On the Meteorology of Toronto in Canada.

By Lieut.-Colonel Edward Sabine, *R.A., F.R.S.*

[A communication made to the Mathematical and Physical Section at the York Meeting, and directed to be printed entire amongst the Reports.]

The subject which I am about to bring before the Section consists of a portion of the results of the meteorological observations which have been made at the magnetical and meteorological observatory at Toronto in Canada, in the first two years of its establishment. It is well known to the members of the Section, that in conformity with the recommendation made by this Association, the British Government has formed establishments in various parts of the globe, for the purpose of making magnetical and meteorological observations on a systematic plan, and has created a department for the reduction and publication of the observations. As the officer entrusted with the conduct of these operations, I regard it as not less a duty than a pleasure, to communicate, from time to time, at the meetings of the British Association, such of the arrangements, or of the observations themselves, or of the conclusions to which they may have led, as I may suppose may be interesting to its members. I have accordingly selected for the present occasion some portion of the results which the meteorological observations at Toronto, in 1841 and 1842, have yielded, when subjected to a full process of reduction, and carefully examined. I have preferred the meteorological to the magnetical observations, partly on account of the more popular character of the subject generally, and partly because the conclusions to which the meteorological observations have already conducted appear to possess a completeness and fullness not yet attained in magnetism. The observations, which will be treated of in this communication, were made at every second hour throughout the year, except on Sundays, Christmas day, and Good Friday. Subsequently to the period which will be now passed in review, they have been made hourly, and the results of these may possibly be brought before the Section on a future occasion.

For the purpose of rendering this communication more interesting and more useful, I have compared the meteorological results obtained at Toronto with those obtained by M. Kreil at the magnetical and meteorological observatory at Prague in Bohemia*. It is frequently found that we gain more by such comparisons,—by the points of resemblance and points of difference, and by the analogies and contrasts which they bring to our notice,—than we do by a simple direct investigation.

Prague like Toronto is situated at a considerable distance from the ocean (between 300 and 400 miles) in the interior of a great continent, the latitude and elevation moreover not being very dissimilar. The agreement which will be shown in the leading features of their meteorology manifests that these features belong to a locality so circumstanced, whether the continent be Europe or America; whilst the minor differences point to climatological distinctions of a secondary order, important indeed to discuss from their bearing on the health and occupations of mankind, as well as in more purely scientific respects, but into which time will scarcely permit me to enter on the present occasion beyond a mere notice of some of the facts.

In all comparisons between places situated in Europe and in North America, there is one leading difference in respect to temperature which we must expect to find, which is doubtless familiar to all the members of the Section, viz. that in Europe we enjoy a climate of higher mean temperature in proportion to the latitude than is the case in America; in other words, that the isothermal lines descend into a lower latitude in America than they do in Europe. It would occupy far too much time to discuss, on the present occasion, the causes of this great climatological difference; they have been largely discussed by many eminent philosophers; but it may be well, before we proceed to further details, to notice briefly the *amount* of difference in this respect which is shown by the observations at Prague and Toronto.

The following statement exhibits the particulars of the latitude, elevation above the sea, and mean temperature of the two stations; as well as the correction of the difference of their mean temperatures on account of difference of elevation:—

Toronto, latitude	43° 39′	Elevation	330 feet.
Prague, „	50 05	„	582 „
Difference	6 26	Difference	252

Prague should be colder on account of its elevation . 0°·8 Fahr.

Mean temperature, Toronto	44°·4	Difference ...	4 ·3
„ Prague .	48 ·7 †		
Difference of temperature corrected for difference of elevation		Prague warmer	5 ·1

Whence it appears that Prague is 5°·1 warmer than Toronto, although its latitude is 6° 26′ more distant from the equator.

TEMPERATURE.

We will now proceed to the distribution of the mean temperature into the several hours of the day, and into the several months of the year; the first, forming the *diurnal* variation of the temperature, or that variation which has *a day* for its period; the second, the *annual* variation, or that variation which has *a year* for its period.

Diurnal Variation.—The diurnal variation is the well-known consequence

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* Mag. und Met. Beobachtungen: Prag. 1839-1842.

† Kreil, Jahrbuch für 1843.

of the earth's rotation on its axis. It is a single progression; having but one ascending and one descending branch, the turning points being a maximum early in the afternoon, and a minimum about sunrise. Each hourly mean in each year in the subjoined table is an average of about 311 observations, being one on each day, except Sundays, Good Friday and Christmas day. Each hourly mean of the two years is therefore an average of about 622 observations. The mean temperature of each year, or of all the hours on all the days of the year, rests on about 3732 observations; and the mean temperature of the two years on about 7464 observations. The very small amount of the differences which the table exhibits in the results at the several hours in 1841 and 1842, shows a probability that we have already determined the diurnal march of the temperature, (as far as it can be obtained by two-hourly observations,) with a very near approximation to the truth*.

Mean Annual Temperature at every observation hour.

	6 A.M.	8 A.M.	10 A.M.	Noon.	2 P.M.	4 P.M.	6 P.M.	8 P.M.	10 P.M.	Mid.	2 A.M.	4 A.M.	Mean.
	°	°	°	°	°	°	°	°	°	°	°	°	°
Toronto. 1841...	39·0	42·4	46·2	48·8	50·4	50·3	48·1	44·0	42·0	40·7	39·5	38·8	44·2
Toronto. 1842...	39·8	42·9	46·5	49·1	50·7	50·8	48·2	44·2	42·3	41·0	40·2	39·6	44·6
Toronto. Mean.	39·40	42·65	46·35	48·95	50·55	50·55	48·15	44·10	42·15	40·85	39·85	39·20	44·4

Temperature at the several observation hours higher (+) or lower (—) than the Mean Annual Temperature.

Toronto....	— 5·0	— 1·75	+ 1·95	+ 4·45	+ 6·15	+ 6·15	+ 3·75	— 0·3	— 1·25	— 3·55	— 4·55	— 5·2	
Prague......	— 4·7	— 2·6	+ 0·9	+ 3·8	+ 5·2	+ 5·1	+ 3·7	+ 0·8	— 1·1	— 2·3	— 3·4	— 4·4	

Toronto proportionally colder (—) or warmer (+) than Prague at the several observation hours.

	— 0·3	+ 0·85	+ 1·05	+ 0·65	+ 0·95	+ 1·05	+ 0·05	— 1·1	— 0·15	— 1·25	— 1·15	— 0·8	

If we take the difference between the mean temperature at Toronto derived from all the observations (44°·4), and the mean of all the temperatures observed at each of the observation hours, we have the mean diurnal march of the thermometer as shown in the table, or how much the temperature amount is above or below its mean at each hour of observation.

In the line immediately beneath the diurnal march of the temperature at Toronto, is placed the diurnal march at Prague, by which means the general resemblance and the minor differences can be at once perceived by the eye.

These latter are further shown in the last line, which points out the hours when the temperature is proportionally warmer at Toronto than at Prague, which hours have a + sign before them, and those when it is proportionally colder, which are characterized by the — sign. It will be at once obvious that the climate at Toronto is proportionally warmer during the hours of the day, and colder during those of the night, than at Prague. Toronto being in a lower latitude and therefore nearer the sun, the sun's influence is proportionally greater during the hours of the day; but in the absence of the sun, the powerful causes which, in spite of the difference of latitude, depress the isothermal lines, show their unchecked influence in the proportionally lower temperature of the hours of the night. So strong indeed are those causes, that at no one hour of the twenty-four does the absolute temperature at Toronto rise to an equality with that of Prague.

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* The building of the observatory at Toronto having been completed in September 1840, the observations now under notice commence with October 1840. The year 1841 in this communication is therefore more strictly the year which commences October 1, 1840, and ends September 30, 1841. In like manner 1842 commences with October 1, 1841, and ends with September 30, 1842.

The nights being proportionally colder and the days warmer than at Prague, the mean daily range of the thermometer is greater, being 9°·9 at Prague and 11°·35 at Toronto. The mean temperature of the 24 hours occurs earlier in the forenoon and earlier in the afternoon at Toronto than at Prague.

Annual Variation.—The next table exhibits the mean monthly temperatures in each month of 1841 and 1842, and their average. In a separate column is shown the amount by which the temperature in each month exceeds or falls short of the mean temperature of the year. This forms the annual variation of the temperature; it is, as is well known, the consequence of the earth's annual motion in its orbit, which regulates the order and succession of the seasons, and occasions a progression of temperature from a minimum in the midwinter to a maximum in the midsummer. This also is a single progression, having but one ascending and one descending branch. The annual variation of the temperature at Prague is placed by the side of that at Toronto, by which means the eye is at once enabled to judge of the general agreement and the minor differences; the latter are also shown more distinctly in the final column.

	Toronto.			Prague. Mean of 20 years.	The several months above (+) or below (−) the annual mean.		Toronto proportionally hotter (+) or colder (−) than Prague.
	1841.	1842.	Mean.		Toronto.	Prague.	
January	25°·6	27°·8	26°·7	26°·9	−17°·7	−21°·8	+4°·1
February	23·2	28·0	25·6	30·8	−18·8	−17·9	−0·9
March	28·1	36·2	32·1	38·6	−12·3	−10·1	−2·2
April	39·5	43·6	41·6	48·8	− 2·8	+ 0·1	−2·7
May	51·2	49·8	50·5	58·0	+ 6·1	+ 9·3	−3·2
June	66·1	56·6	61·3	64·6	+16·9	+15·9	+1·0
July	65·4	64·8	65·1	68·1	+20·7	+19·4	+1·3
August	64·5	65·7	65·1	66·7	+20·7	+18·0	+2·7
September	61·3	55·8	58·5	60·2	+14·1	+11·5	+2·6
October	44·7	41·9	43·3	50·1	− 1·1	+ 1·4	−2·5
November	35·7	35·3	35·5	38·8	− 8·9	− 9·9	+1·0
December	24·8	29·8	27·3	33·0	−17·1	−15·7	−1·4
Mean	44·2	44·6	44·4	48·7			

Difference between the hottest and coldest month.
Prague ...... 41°·2
Toronto...... 39°·5

In viewing the minor differences shown in the last column, we must not overlook that our numbers are based on two years only of observation, and that for an *annual* progression, a single year forms in fact but a single experiment. When we view the differences which some of the months present in the columns representing the observations in 1841 and 1842, we shall readily acknowledge that more than two years are required to give that approximation to a mean annual progression which the present state of science requires. There are, however, some features of difference which present such obvious characters of system that we may have reason to expect that the observations of a greater number of years will but make them more assured. Thus the spring months are all proportionally colder, and the summer months hotter, at Toronto than at Prague. There is also one remarkable difference, viz. in January, which is proportionally a colder month by above 4° at Prague than at Toronto; and from the magnitude of the amount, it wears the aspect of a permanent climatological difference. Now it is well known that in the month of January the wind from the east and north-east prevails in Europe, bringing with it our severest winter cold. This feature has not a parallel in North America, where the cold of winter is more equably distributed. It would occupy too much time to discuss the cause of this peculiarity in the European climate; and I must content myself with referring generally to M. Dove's elaborate work on the distribution of temperature; a work which cannot fail to impress the reader strongly with the value of the conclusions to be derived from long-continued series of observations subjected to a laborious and persevering study. It is a curious result from this excess of cold in Europe in January, that notwithstanding the greater proportional warmth in summer and cold in spring at Toronto, the extreme difference, or that between the coldest and the warmest month of the year, is absolutely greater at Prague than at Toronto, being 41°·2 at Prague and 39°·5 at Toronto.

It is a consequence of the minor differences already pointed out, that a temperature equal to that of the mean temperature of the year occurs later in spring and earlier in autumn at Toronto than at Prague; and that the temperature is higher than the mean of the year during seven months at Prague, whilst at Toronto it is only so during five months.

I have inserted in the next table the mean *range* of the thermometer during three years at Toronto and at Prague. It must be understood that the maximum of each month inserted in this table is the *mean* maximum during three years; viz. March 1840 to March 1843 at Toronto; July 1839 to July 1842 at Prague; and the same is to be understood of the minimum: the range is consequently a *mean* range during three years, and is of course exceeded by the range in individual years.

Range of the Temperature in different Months.

	Toronto (3 years).			Prague (3 years).		
	Max.	Min.	Range.	Max.	Min.	Range.
January	+47°·3	+ 1°·8	45°·5	+46°·8	+ 4°·0	42°·8
February	+42·7	− 1·0	43·7	+43·9	+ 1·6	42·3
March	+59·1	+ 7·0	52·0	+54·8	+13·8	41·0
April	+72·3	+23·0	49·3	+72·6	+29·1	43·5
May	+75·7	+29·5	46·2	+83·5	+40·0	43·5
June	+82·3	+37·2	45·1	+88·0	+47·0	41·0
July	+85·5	+45·1	40·4	+92·0	+50·6	41·4
August	+81·8	+47·0	34·8	+84·0	+48·4	35·6
September	+78·2	+32·0	46·2	+82·5	+40·2	42·3
October	+65·6	+25·5	40·1	+69·8	+31·4	38·4
November	+57·6	+12·7	44·9	+59·5	+29·5	30·0
December	+42·6	+ 3·7	39·0	+47·0	+12·4	34·6
	Mean range ...		43·9	Mean range ...		39·7

Toronto	Highest, June 29, 1841	+91·7	Prague	Highest, July 18, 1841	+97·8
	Lowest, Feb. 16, 1842	− 8·2*		Lowest, Dec. 15, 1840	− 7·0
	Range ...	99·9		Range ...	104·8

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* The thermometer ranged much lower in January 1840, before the commencement of the series under notice, viz.—

January 2nd	− 17·5	January 15th	− 8·5	
„ 3rd	− 9·2	„ 16th	− 15·0	
„ 4th	− 10·0	„ 17th	− 19·2	lowest observation.

Here also the general character shown by the comparison of the two stations is that of very close resemblance, while the minor differences also stand out prominently. The greater variation to which the temperature is subject at Toronto in March and April is very obvious in the column of range; as is also the small amount of the variation in the month of November at Prague. The mean monthly range deduced from the twelve months is 43°·9 at Toronto, and 39°·7 at Prague; a considerable amount of difference, and which marks the greater general vicissitude of the climate of Toronto: still it is deserving of notice that Prague is occasionally liable to fully as great, and (during these three years at least) even greater extremes of temperature than Toronto, as is shown by the memorandum at the foot of the table; it is indeed curious to remark how very nearly the stations approach each other in the extreme amount of their thermometrical range. July and August are the only months in which during three years the observations at Toronto never show a temperature of the air so low as the freezing point. At Prague there are five months, viz. from May to September inclusive, in which during the three years the temperature was never observed so low as 32°.

If we seek in the old continent a station most nearly isothermal with Toronto, we must refer to a latitude considerably higher than Prague. The station in M. Mahlmann's list (Dove, Repertorium, b. 4, and Humboldt, Asie Centrale, tom. 3.), which most nearly resembles it in the mean temperature of the different seasons, as well as in that of the whole year, is Wexiö in Sweden, in latitude 56° 53′, and height above the sea 450 Parisian feet. Toronto is in 43° 39′, and height above the sea 330 English feet. The mean temperatures are—

	Spring.	Summer.	Autumn.	Winter.	Annual.	Coldest month.	Warmest month.
	°	°	°	°	°	°	°
Toronto	41·4	63·8	45·8	26·5	44·4	25·6	65·1
Wexiö	41·5	63·8	44·8	27·8	44·5	27·0	66·0

AQUEOUS VAPOUR.

I proceed to consider the elastic force or tension of the aqueous vapour contained in the atmosphere, and the degree of humidity produced by it, together with the diurnal and annual variations of these phænomena.

The elastic force of the vapour is considered to be one of the constituents of the pressure upon the surface of the mercury in the cistern of the barometer, which, conjointly with the other and much larger constituent, viz. the pressure of the gaseous atmosphere, produces what in common parlance is called the *pressure of the atmosphere*, measured by the height of the mercurial column in the barometer. Although we have no instrument by which we can measure the gaseous pressure independently of that of the aqueous vapour, we possess in Daniell's hygrometer, and in the wet and dry thermometers, the means of ascertaining the aqueous pressure at any instant independently of the gaseous pressure; and therefore, by the combination of the barometer and of the wet and dry thermometers (or of the hygrometer before mentioned), we should be able to obtain separately the pressure due to each constituent, and the annual and diurnal variations of both. It will be understood, therefore, that when the "tension of the vapour" is here mentioned, it expresses also the pressure on the barometer produced by the elastic force of the vapour present in the air.

The scale in which the humidity of the air is expressed is the simple natural scale in which air at its maximum of humidity (*i.e.* when it is saturated with vapour) is reckoned as = 100; and air absolutely deprived of moisture as = 0: the intermediate degrees are given by the fraction

$$\frac{100 \times \text{actual tension of vapour,}}{\text{tension required for the saturation of the air at its existing temperature.}}$$

Thus if the air at any temperature whatsoever contains vapour of half the tension which it would contain if saturated, the degree is 50; if three-fourths, then 75; and so forth.

Air of a higher temperature is capable of containing a greater quantity of vapour than air of less temperature; but it is the proportion of what it *does* contain to what it would contain if saturated, which constitutes the measure of its dryness or humidity.

The capacity of the air to contain moisture being determined by its temperature, it was to be expected that an intimate connexion and dependence would be found to exist between the annual and diurnal variations of the vapour and of the temperature. I shall proceed to show how distinctly and fully this connexion is exhibited by the observations at Toronto. We will commence with the humidity.

Diurnal Variation.—The degree of humidity at the several observation hours exhibits, as in the case of the temperature, a simple progression of one ascending and one descending branch, having its turning points the same as those of the temperature, namely, a maximum at or near the coldest, and a minimum at or near the hottest hours of the day; the progression is inverse, but is in harmony with that of the temperature.

Mean degree of Humidity at Toronto at the several Observation Hours.

	6 A.M.	8 A.M.	10 A.M.	Noon.	2 P.M.	4 P.M.	6 P.M.	8 P.M.	10 P.M.	Mid.	2 A.M.	4 A.M.	Mean.
1841...	88	83	77	73	70	69	72	79	82	84	85	86	79
1842...	86	81	73	70	68	67	71	78	81	82	84	84	77
Mean.	87	82	75	71·5	69	68	71·5	78·5	81·5	83	84·5	85	78

The accord of the two years' observations is remarkably satisfactory; they unite in showing that in the average state of the atmosphere at Toronto, the air is charged with between three-fourths and four-fifths (or more exactly with 78 parts in 100) of the vapour required for its saturation.

When we proceed to the mean tension of the vapour at the several observation hours, we perceive an accord with the march of the temperature fully as striking; one ascending, one descending branch;—the turning points in obvious dependence,—and the march harmonious; in this case the progression is direct, in relation to that of the temperature,—as it was inverse in the case of the humidity.

Mean Tension of the Vapour at the several Observation Hours.

	6 A.M.	8 A.M.	10 A.M.	Noon.	2 P.M.	4 P.M.	6 P.M.	8 P.M.	10 P.M.	Mid.	2 A.M.	4 A.M.	Mean.
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
1841...	·249	·268	·282	·293	·296	·287	·276	·264	·254	·251	·243	·240	·267
1842...	·234	·251	·259	·271	·275	·273	·263	·250	·245	·236	·233	·229	·252
Mean.	·242	·260	·270	·282	·285	·280	·269	·257	·250	·243	·238	·234	·259

The direct evidence of connexion and dependence exhibited in the diurnal march of the vapour and temperature at Toronto is the more deserving of our notice, because in many climates, this connexion, though it always exists, is partly obscured by other less direct influences of the temperature. Thus at Trevandrum, in the East Indies, where the zeal of our indefatigable associate Mr. Caldecott, Director of the Magnetical and Meteorological Observatory established by His Highness the Rajah of Travancore, has already accumulated, reduced, and transmitted to England five years of hourly observations with the wet and dry thermometers, the maximum and minimum of the tension are found to occur within three hours of each other; the minimum coinciding with the coldest hour, viz. at 6 A.M.; but the maximum occurring at 9 in the forenoon. This may possibly be a consequence of the sea breeze, which springs up as the sun gains power, and as the earth warmed by the solar rays heats the air in contact with itself and causes it to rise, occasioning an inpouring of the air from over the surface of the ocean. The sea breeze brings an influx of fresh air charged with vapour; the air in its turn is heated and ascends, but the vapour is subject to a different law; and though a portion of it is doubtless rapidly conveyed upwards by the ascending current, it is probably the accumulation below which causes an immediate rapid rise in the tension of the vapour, making its maximum to occur at a very early hour. The few facts which are yet known regarding the diurnal march of the vapour in different parts of the globe, present many phænomena of this nature, which at first sight appear inconsistent with the dependence of the progression of the vapour on that of the temperature; but which, when duly explained, will doubtless be found directly or indirectly in accordance with it. The knowledge of the phænomena of the vapour in different climates and under different circumstances (such as in insular, littoral, or continental situations, &c.), with the explanation of the various peculiarities which they present, will form hereafter a very interesting and beautiful chapter in the physical history of the globe.

Annual Variation.—We will now proceed to the mean *monthly* humidity and mean *monthly* tension exhibited in the following tables:—

Mean Monthly Humidity.

	Toronto.			Greater (+) or less (−) than the annual mean.
	1841.	1842.	Mean.	
Jan......	87	81	84	+ 6·0
Feb......	80	84	82	+ 4·0
March .	79	76	77·5	− 0·5
April ...	70	71	70·5	− 7·5
May.....	67	64	65·5	− 12·5
June ...	72	76	74	− 4·0
July	74	74	74	− 4·0
Aug.....	81	79	80	+ 2·5
Sept. ...	83	78	80·5	+ 3·0
Oct. ...	84	78	80·5	+ 3·0
Nov.....	86	81	83·5	+ 5·5
Dec.....	84	86	85	+ 7·0
Mean....	79	77	78	

Mean Monthly Tension.

	Toronto.			Greater (+) or less (−) than the annual mean.
	1841.	1842.	Mean	
	In.	In.	In.	
Jan. ...	·135	·130	·132	− ·127
Feb. ...	·107	·138	·123	− ·136
March..	·131	·162	·146	− ·113
April ...	·173	·199	·186	− ·073
May ...	·259	·227	·243	− ·016
June ...	·452	·347	·399	+ ·140
July	·449	·438	·443	+ ·184
Aug. ...	·482	·491	·486	+ ·227
Sept. ...	·453	·351	·402	+ ·143
Oct......	·254	·210	·232	− ·027
Nov. ...	·185	·173	·179	− ·080
Dec.....	·122	·153	·138	− ·161
	·267	·251	·259	

We perceive by the table in which the mean monthly humidity is shown, that the months from March to July are drier than the average of the year, and that the remaining months are more humid than the average. The drier months are those in which the temperature of the air is rising; the most humid those in which the temperature is either falling or nearly stationary. When the temperature is rising the warmth increases more rapidly than the air receives the addition to its vapour required to maintain an equal degree of humidity, and the air becomes in consequence drier. This is even the case in the neighbourhood of extensive lakes, as at Toronto. May is the driest and December the most humid month in the year: and this is also stated to be the case in Europe.

When we turn to the table in which the mean monthly tension of the vapour is shown, we see most distinctly marked the connexion between the temperature and the vapour pressure, and the dependence of the one upon the other; we see a simple progression, the turning points being the same as those of the temperature, and a march as harmonious as we are perhaps entitled to expect from observations of only two years' continuance.

I shall reserve what further I may have to say in regard to the *range* of the vapour-pressure in different months, until we have before us the other constituent of the barometric pressure, viz. the gaseous atmosphere, to which I now proceed.

ATMOSPHERIC PRESSURE.

		Toronto.												
		6 A.M.	8 A.M.	10 A.M.	Noon.	2 P.M.	4 P.M.	6 P.M.	8 P.M.	10 P.M.	Mid.	2 A.M.	4 A.M.	Mean.
Mean bar. Pressure.. 29 inch. +	1841.	·624	·637	·638	·616	·595	·591	·598	·609	·613	·607	·606	·610	·612
	1842.	·613	·628	·631	·612	·594	·590	·595	·602	·603	·596	·593	·595	·604
	Mean.	·618	·632	·634	·614	·594	·590	·596	·605	·608	·601	·600	·602	·608
Deduct pressure of the vapour..		·242	·260	·270	·282	·285	·280	·269	·257	·250	·243	·238	·234	·259
Press. of the gaseous atmosph. 29 inches + ..		·376	·372	·364	·332	·309	·310	·327	·348	·358	·358	·362	·368	·349
Pressure at each hour greater (+) or less (−) than the mean annual pressure		+·027	+·023	+·015	−·017	−·040	−·039	−·022	−·001	+·009	+·009	+·013	+·019	

Diurnal Variation.—The first two lines of this table exhibit the mean monthly pressure on the mercurial column at Toronto at the several observation hours of 1840 and 1841,—the mean of the two years is shown in the third line. The close accord of the mean pressure at the same hours in each of the two years is a very satisfactory testimony of the confidence to which these barometrical results are entitled: the mean at each hour of each year represents about 311 observations; consequently in the two years the mean at each observation hour represents about 622 observations, the mean of all the hours in the one year 3732 observations, and in the two years 7464 observations.

The diurnal march of the barometer may consequently be regarded as a very near approximation to the truth. The diurnal march of the vapour pressure is obtained by an equal number of observations, and may therefore also be viewed as a very near approximation to the facts of nature. By deducting the vapour pressure from the whole barometric pressure at each observation hour, we should obtain the daily march of the gaseous atmosphere. This is shown in the fifth line of figures in the table; and by taking the difference between the last column, (*i. e.* between the mean gaseous pressure at all the observation hours in the two years,) and the pressure at each hour, we obtain the amount by which the pressure is greater or less at each observation hour than the mean general pressure at all the hours.

On first casting our eyes (in the last line of the preceding table) on this representation of the diurnal variation of the gaseous atmosphere, freed from the complication which its combination with the vapour pressure produces in the indications of the barometer, we cannot fail to be immediately struck with the very close correspondence of the diurnal march before our eyes with that of the temperature which we have already examined. The maximum of pressure is at 6 A.M.; the minimum at 2 P.M. The progressions take place in the opposite or inverse sense to each other, but they are remarkably harmonious, and leave no doubt of a mutual connexion, and of the dependence either of the one on the other, or of both on a common cause.

An explanation of this connexion, which presents itself to the mind as soon as the facts are clearly perceived, may be thus stated :—As the temperature of the day increases, the earth becomes warmed and imparts heat to the air in contact with it, and causes it to ascend. The column of air over the place of observation thus warmed rises, and a portion of it diffuses itself, in the higher regions of the atmosphere, over adjacent spaces where the temperature at the surface of the earth is less. Hence the statical pressure of the column is diminished. On the other hand, as the temperature falls, the column contracts, and receives in its turn a portion of air which passes over in the higher regions from spaces where a higher temperature prevails; and thus the statical pressure is augmented.

This explanation is merely the extension to the particular case of the diurnal variation, of principles which have long been familiar to meteorologists in accounting for various other atmospherical phænomena, such for example as monsoons, and land and sea breezes. To make the parallel complete, it should be shown that, when the temperature rises, an influx of air takes place towards the lower part of the column, proportioned to the ascending current, and tending to replace the air which is thus removed. The observations which will be cited in the sequel of this communication will show that such is precisely the fact at Toronto. The force of the wind, taken without reference to its direction, has also its diurnal variation, corresponding in all respects with the diurnal march of the temperature and of the gaseous pressure; being a minimum at 6 A.M., and a maximum at 2 P.M.—increasing with the augmentation of the temperature, and decreasing with its diminution. The air which thus flows in, becoming warmed, pursues in its turn the course of the ascending current. We have thus the double evidence of the existence of this current,—1st, in the diminution of pressure, showing the outpouring at one extremity; and 2nd, in the increased force of the wind, showing the inpouring at the other extremity. As the temperature keeps *continually* rising, both the demand for and the supply of fresh inflowing air progressively increase. The diminution which the gaseous pressure continues to undergo as long as the temperature continues to rise, shows, as we might naturally expect, that the supply is continually somewhat in arrear of the demand.

The diminution of the gaseous pressure and increase in the force of the wind being consequent on the rise of the temperature, the turning points of the two former phænomena might be expected to occur somewhat later than the instant of minimum temperature; and this appears by the tables to be the case, but will probably be more clearly shown when the hourly observations shall come under review.

Annual Variation.—Let us now proceed to the mean pressure of the gaseous atmosphere in each *month* of the year, and its consequent *annual* variation. These are shown in the following table:—

MEAN MONTHLY PRESSURE.

	Toronto.						Prague.	
	Barometer.			Vapour.	Gaseous pressure.	Gaseous pressure in each month greater (+) or less (−) than the mean annual pressure.	Gaseous pressure.	Gaseous pressure in each month greater (+) or less (−) than the mean pressure.
	1841.	1842.	Mean.					
January	29·664	29·508	29·586	·132	29·454	+·105	29·213	+·194
February......	·489	·548	·518	·122	·396	+·047	29·227	+·208
March.........	·657	·638	·647	·146	·501	+·152	29·089	+·070
April	·621	·548	·584	·186	·398	+·049	28·973	−·046
May	·545	·586	·565	·243	·322	−·027	28·923	−·096
June	·543	·585	·564	·399	·165	−·184	28·898	−·121
July............	·620	·655	·637	·443	·194	−·155	28·861	−·158
August	·698	·712	·705	·486	·219	−·130	28·882	−·137
September ...	·606	·662	·634	·402	·232	−·117	28·912	−·107
October	·636	·643	·639	·232	·407	+·058	29·045	+·026
November ...	·615	·568	·592	·179	·413	+·064	29·047	+·028
December ...	·652	·597	·625	·137	·488	+·139	29·163	+·144
Mean	29·612	29·604	29·608	·259	29·349		29·019	

In turning our attention to the column which exhibits the excess or defect of the mean monthly pressure on the mean of all the months, we at once perceive another illustration of the principle which has been just stated. We find the pressure of the gaseous atmosphere diminished in the summer months and augmented in the winter months. The general dependence on the march of the temperature is manifest; and it must remain for the additional evidence which will be produced by the observations of subsequent years, to determine, whether the minor deviations from a perfectly harmonious march are mere accidental differences, which a wider observation basis will cause to disappear, or whether they may not point to some other periodical influence (possibly of the temperature also, but of a less direct nature) which is as yet unrecognized*.

I will now ask the Section to turn its attention for a moment to the column which presents the mean height of the *barometer* in each month of the year. It is curious to observe how completely the annual march of the gaseous atmosphere is masked in the barometer by its combination with the vapour pressure, both being measured in one by the mercurial column; the increase of temperature, which causes the gaseous pressure to diminish, occasions the increase of the vapour, and *vice versâ*; and so nearly are these two opposite effects of the one cause balanced at Toronto, that the height of the barometer remains very nearly the same in every month of the year; or at least, shows no trace whatsoever of an annual period.

The principle which has been thus adduced for the purpose of explaining the annual and diurnal march of the atmospheric pressure should be ge-

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* The very few meteorological registers, which have been maintained with proper care for several years together in Europe, are stated to afford very decided indications of the existence of other fluctuations besides the annual and diurnal variations, which apparently do not proceed from merely local causes, but recur regularly at stated periods of the year, and are recognisable simultaneously over widely extended spaces, such for example as a considerable portion of an entire continent. How far the high pressure of the month of March at Toronto may be a phænomenon of this class it may perhaps take some years to decide. It is of very marked character, and is shown decidedly in both years. As I have already remarked, each year is but a single experiment in investigations of annual phænomena.

neral in its application. I have inserted in the table the gaseous pressure at Prague, as it is given by M. Kreil in his 'Jahrbuch' for 1843, from the observations of three years. The march of the vapour, as far as it has yet been determined at Prague, does not present a curve agreeing quite so satisfactorily with that of the temperature as we have been able to deduce at Toronto: whether this arises from disturbing influences in nature (such possibly as indirect influences of temperature), or whether it will disappear by longer-continued observation, cannot be yet anticipated. What is still uncertain, however, at Prague, is not of magnitude sufficient to obscure the dependence of the annual progression of the gaseous pressure on that of the temperature. The measure of agreement in this respect at the two stations cannot be viewed otherwise than as highly interesting and satisfactory. Mean quantities derived from a greater number of years will in all probability show even a closer accordance.

We will now revert to the maximum, minimum and range of the vapour pressure in the several months of the year, for the purpose of showing that its variations are such, as to seem to claim a greater attention than they have hitherto received, at the hands of those who are engaged in investigating the non-periodic fluctuations of the atmosphere, by the comparison of observed barometrical heights. In the next table we have the maximum, minimum, and range of the vapour pressure at Toronto, taken from the mean of two years. By thus exhibiting the mean quantities only of the two years of observation, extremes are of course somewhat moderated; but, on the other hand, there is the advantage that the numbers are probably a more faithful representation of what may be expected in ordinary course.

Range of the Barometer.			Maximum, Minimum, and Range of the Tension of Vapour.					
	Toronto.	Prague.	Toronto—Mean of 2 years.			Prague—Mean of 2 years.		
			Max.	Min.	Range.	Max.	Min.	Range.
	in.	in.	in.	in.	in.	in.	in.	in.
January	1·335	1·364	·221	·050	·171	·306	·051	·255
February.........	1·221	1·156	·262	·050	·212	·238	·052	·186
March............	1·275	1·158	·350	·045	·285	·278	·067	·211
April	1·190	0·864	·385	·085	·300	·406	·149	·257
May	0·846	0·881	·532	·105	·427	·555	·163	·392
June	0·623	0·873	·709	·143	·566	·659	·222	·437
July..............	0·696	0·593	·775	·202	·573	·662	·245	·417
August	0·656	0·647	·762	·262	·498	·556	·257	·299
September	0·754	0·755	·727	·158	·569	·567	·217	·350
October	0·934	0·829	·487	·096	·391	·447	·124	·323
November	0·945	1·036	·375	·066	·309	·414	·138	·276
December	1·527	1·222	·263	·048	·215	·300	·058	·242
Mean	1·000	0·950	·486	·109	·377	·449	·145	·304

We here perceive that the mean monthly range of the tension of the vapour falls little short of four-tenths of an inch; and that in the summer months of June, July, August, and September, when it is greatest, it is very little less than the whole range of the barometer in the same months. Winter is the season for the great fluctuations of the barometer; summer for those of the vapour pressure. If, as is believed by many modern meteorologists, the fluctuations of the vapour pressure affect the barometer to their whole extent, then the fluctuations of the gaseous atmosphere at Toronto approach much nearer to an equality in the two seasons of summer and winter, than do those of the barometer. A north-west wind at Toronto is usually accompanied by a rise in the barometer and a fall in the temperature with a diminution in the tension of vapour; and a south or south-east wind, by a fall in the barometer and a rise in the thermometer with an increased tension of vapour. In a change from one of these winds to the other, consequently, the alteration of the gaseous pressure would be greater than that of the barometric pressure, which is partially counteracted by the accompanying change in the elastic force of the vapour: and as already noticed, the fluctuations in the vapour pressure are very considerable in summer. I have selected some remarkable instances in a single year, 1841, which are as follows:—

Variations of Vapour Pressure in 1841.

		d.	h.			d.	h.				
Between	May	30	16	and	June	5	4	under	6	days	0·594
„	June	11	0	„	June	15	10	„	5	„	0·503
„	June	30	2	„	July	2	6	„	3	„	0·610
„	July	2	6	„	July	5	4	„	3	„	0·465
„	July	23	4	„	July	25	16	„	3	„	0·500
„	Aug.	18	2	„	Aug.	23	14	„	6	„	0·496

If the principles are correct, of which we have here traced a portion of the consequences, barometrical observations generally must lose an essential part of their value when unaccompanied by hygrometrical observations, by means of which the pressures of the air and vapour may be separated. Whenever such complete observations are made, *i.e.* hygrometric as well as barometric, the tension of vapour should be computed on the spot and at the instant. When calculations of this nature are suffered to fall in arrear, unreduced observations accumulate, and danger is incurred that the calculations are never made, and that science will lose the advantage which the observations were capable of affording.

The comparison of the barometric range in the different months at Toronto and Prague exhibits a very satisfactory accordance, and shows how similar are the phænomena which present themselves in this respect over the two continents.

The comparison of the range of the vapour pressure at Prague and Toronto exhibits only such differences as may be reasonably ascribable to the greater range of the temperature at Toronto, and possibly to the greater facility with which the air can acquire vapour at that station from the great lakes in its vicinity.

It may be worthy of notice, that the highest and lowest barometric observations in the two years at Toronto occurred within a very few days' interval of each other, being apparently parts of one great atmospheric wave.

The highest and lowest barometric observations at Prague also took place within a few days of each other, and at the same season, viz. midwinter, but a year earlier. The observations were as follows, viz.—

Extreme Range of Barometer in 1840, 1841.

	Toronto.		Prague.	
Max.	Dec. 22, 1841	30·417	Dec. 27, 1840	30·260
Min.	Dec. 4, 1841	28·672	Jan. 4, 1841	28·654
	Interval 18 days. . . .	1·745	Interval 9 days	1·606

We have undoubtedly made a considerable step in advance in meteorology, if we thus correctly substitute the consideration of the separate daily march of the pressures of the vapour and of the gaseous atmosphere, for the comparatively profitless study of the complex effect produced on the barometer by the operation of these two distinct agencies. The labour has been by no means small which has been bestowed in the endeavour to generalise the diurnal phænomena of the barometer by the formation of empirical formulæ; it has been in many instances the labour of highly accomplished men: but we have the recent acknowledgment of a valued and distinguished member of our own body*, who has himself engaged in this inquiry, that it failed in conducting to a recognition of the causes of the phænomena. On the other hand, the moment we apply ourselves to the contemplation of the separate phænomena of the vapour and of the air, there appears to be revealed to us a simple and beautiful dependence of each upon the diurnal march of the temperature, producing effects which in their combination seem also to afford a full and perfect solution of the problem of the daily rise and fall of the barometric column.

It would be unjust to the meteorologists of Germany if we were not gratefully to acknowledge in how great a degree this advance in the science is to be ascribed to their writings, and especially to those of M. Dove. Their meteorological researches have been pressed with an assiduity and devotion of labour which is beyond all praise. In the consideration which we (the members of the British Association) are likely soon to be called upon to exercise, whether any and what great combined endeavours are further desirable to be made for the advancement of meteorological science, we should be indeed inexcusable if we neglected to avail ourselves of the advice, and look with becoming respect to the opinions, of men, who have spent years of untiring labour, and brought great attainments to bear, on a branch of science which has been comparatively less cultivated by ourselves.

Admitting M. Dove's views, we can easily perceive that an empirical formula, in which the diurnal oscillation of the barometer should be made to vary as a function of the latitude, could never universally represent the phænomena. The difference between an insular or littoral station, where the vapour pressure attains its maximum at 9 in the forenoon, and an interior station in the same latitude where the maximum is at 2 or 3 in the afternoon, cannot both be represented with fidelity by a formula in which this difference is not taken into the account. At stations where the maximum of vapour pressure takes place at 9 A.M., and the tension thenceforward descends until the afternoon,—(as at Trevandrum),—the range of the diurnal oscillation of the barometer will be greater, *ceteris paribus,* than when, as at Toronto, the vapour pressure progressively rises from sunrise to a maximum at 2 or 3 in the afternoon: the hours of maximum and minimum will also be somewhat modified.

The important problem of the equality or inequality of the mean pressure of the gaseous atmosphere at the level of the sea at different points on the surface of the globe, has lately begun to occupy the attention of physical philosophers in a degree which will probably tend, before many years, to its practical solution. In this labour the determinations of our co-operative observatories may perform an important part. Great care has been taken that the barometers of our colonial observatories shall speak precisely the same language as the standard barometer in the Royal Society's Apartments; and steps are now taking to ensure a similar comparison of the barometers, which, in different parts of the United States, are now observed simultaneously with Toronto by our American coadjutors; and which may hereafter, if that observatory should be continued, form a very valuable extensive basis of induction for the movements of the atmosphere over that great continent.

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* Professor J. D. Forbes; Meteorological Report.

Prague and Toronto furnish the materials for an interesting comparison of their respective mean gaseous pressures. I have exhibited this comparison in the subjoined table. After the proper corrections have been applied for the reduction to an invariable scale of pressure, and of the pressure itself to a common elevation above the sea, the residual difference in the pressure is about four hundredths of an inch. This is within the amount of difference that might reasonably be expected in so indirect a comparison. The inference therefore at present must be, that no unaccounted for difference of pressure exists, or at least next to none, at these two stations in Europe and America.

	Inches.
Pressure of the dry atmosphere at Toronto	29·349
Pressure of the dry atmosphere at Prague	29·019
Difference..........	0·330
Reduction to an invariable scale of pressure....	0·017
True difference of pressure..................	0·313
Difference of elevation equivalent to	0·273
Difference of pressure unaccounted for	0·04

Modern researches have shown that the height of the barometer at different points of the earth's surface is not only disturbed by self-adjusting causes which produce temporary displacements, but that there are causes in action which effect persistent differences in the mean height of the barometer in different localities, strictly at the level of the sea; so that, to use the words of Bessel, the mean atmospheric pressure depends on the geographical co-ordinates of a station in latitude and longitude as well as in elevation. This remark of Bessel's is founded chiefly on Erman's observations*; and Erman himself, who has considered the effect of the vapour pressure upon his barometrical heights, concludes that the pressures which the air would have exerted without the presence of aqueous vapour, indicate also persistent differences of mean gaseous pressure depending on geographical position. The instance quoted by Professor Forbes from Captain King†, who found the mean height of the barometer 29·462 in observations repeated five times a day in five consecutive months of summer at Port Famine, is an example of an atmospheric valley, as it has been called, in the former sense, but not in the latter. When allowance is made for the probable vapour pressure, the gaseous pressure at Port Famine will be found greater than its ordinary amount at the Equator; where indeed other observations have indicated a gaseous pressure lower than in the adjacent extra-tropical latitudes.

Assumed equatorial barometer......................	29·95
Deduct vapour pressure (assumed dew point 74°)......	0·83
Mean pressure of the gaseous atmosphere at the Equator	29·12
Barometer at Port Famine in five summer months......	29·462
Deduct vapour pressure (assumed dew point 38°)......	·230
Pressure of the gaseous atmosphere at Port Famine	29·23 ‡

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* Erman, Met. Beob. bei einer Seereise um die Erde.

† Forbes, Reports of the Brit. Assoc., 1832.

‡ This is of course only an approximate comparison; to render it more exact, it would be

In these last remarks I have perhaps ventured further from the strict subject of this communication than I should have been disposed to have done, had I not had in view to call the attention of the Section to what it is in the power of our own country to accomplish, with its widely extended dominions, in the solution of this great problem of the uniformity or otherwise of the mean pressure of the atmosphere, by the establishment of colonial observatories, conducted on a systematic plan, and continuing in operation only until certain specified and definite objects should be attained; such, for example, as the mean values, and the periodical variations, of the several meteorological elements. The present communication is an evidence of the important results which even a very brief duration of such observations may be sufficient to accomplish. When such establishments are proposed, with the sanction and support of the colonial authorities, and with the advantage of men of assured competency to conduct them, we may venture to promise the fullest co-operative aid (that may be compatible with circumstances) on the part of the British Association, which has placed foremost amongst its objects "to give a stronger impulse, and a more *systematic direction* to scientific inquiry."

I have one more point to bring under your notice; a point highly interesting in itself, and completing the evidence of the harmony in the meteorological variations.

It has been noticed that from the diminution of the gaseous pressure as the temperature of the day increases, evidencing an ascending current, we should be prepared to expect a corresponding influx of air at the station, or a diurnal variation in the force of the wind (taken without reference to the direction from which it blows), which should have its minimum at or near the coldest hour of the day, and its maximum at or near the warmest, and its progression in harmony with the curve of temperature, having one ascending and one descending branch. Such is the fact. The subjoined table exhibits the sum of the pressures, expressed in pounds avoirdupois, exerted on a square foot of surface at Toronto, at each of the observation hours in 1841, and the same in 1842. The wind is proverbially uncertain, and our means of measuring its pressure are more imperfect than we could desire; but these numbers afford an ample evidence that there is a diurnal variation in the force of the wind, and furnish a curve which, when projected, is found in remarkable correspondence with the curve of the temperature. This fact, observed at Birmingham by Mr. Osler, has been already brought under the notice of the Association at a former meeting. The diurnal march of the gaseous atmosphere furnishes the additional link in the chain of evidence, by which the connexion between the temperature (producing an ascending current) and the force of the wind (flowing in to replace it) may receive its explanation; placing before us in an intelligible form their mutual relations to each other, as cause and effect.

necessary to regard the influence of the season of the year (summer) at which the barometer was observed at Port Famine; as well as the correction due to the effect of the variation of gravity on the standard of measure. Both corrections would tend to increase the mean pressure of the gaseous atmosphere at Port Famine in comparison with that at the Equator. The barometrical observations made in the Erebus, in the late Antarctic Expedition, furnish a beautiful illustration of the progressive decrease in the height of the barometer from the tropics to the high latitudes, coincident with the diminution of the elastic force of the vapour accompanying the decrease of temperature. I hope that Sir James Ross will shortly publish these interesting observations, with the corresponding pressures of the gaseous atmosphere in the different parallels.

Sum of the pressures exerted by the force of the wind at Toronto on a surface of one foot square at the several observation hours in 1841, 1842.

	6 A.M.	8A.M.	1 A.M.	Noon.	2 P.M.	4P.M.	P.M.	8P.M.	10 P.M.	Mid.	2 A.M.	4A.M.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1841...	96	164	168	186	204	169	120	109	121	111	103	101
1842...	126	156	201	238	285	256	181	123	113	112	128	143
Mean	111	160	184	212	244	212	150	116	117	112	116	122

Without ascribing anything like precision to the numbers in this table (which are however likely to be more correct in relative than in absolute value), they lead to the inference that the pressure of the wind, on the average of the whole year, is doubled, or nearly so, between the coldest and warmest hours of the day; *i. e.* between 6 A.M. and 2 P.M. The confirmation, or otherwise, of this remarkable result by the observations of succeeding years cannot fail to be a point of much interest. It appears from the registry of Mr. Osler's anemometer, during four years at Birmingham, that at that station the increase in the pressure of the wind is considerably more than double between the hours of the minimum and maximum temperature. It will influence many reasonings if it shall be found as a fact of pretty general occurrence, that so large a portion of the daily wind is put in circulation to supply an ascending current*.

Synopsis of the Diurnal Variations at Toronto.

Observation hour.	Temperature.	Vapour pressure.	Gaseous pressure.	Force of wind.
	°	in.	in.	lbs.
2 A.M.	39·8	·238	29·362	116
4 A.M.	39·2 Min.	·234 Min.	29·368	122
6 A.M.	39·4	·242	29·376 Max.	111 Min.
8 A.M.	42·6	·260	29·372	160
10 A.M.	46·3	·270	29·364	184
Noon	48·9	·281	29·333	212
2 P.M.	50·5 } Max.	·285 Max.	29·309 Min.	244 Max.
4 P.M.	50·5	·279	29·311	212
6 P.M.	48·1	·268	29·328	150
8 P.M.	44·1	·257	29·348	116
10 P.M.	42·1	·249	29·359	117
Midnight	40·8	·243	29·358	112

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* To the agency of this current we should probably ascribe the upward conveyance of the vapour of increasing constituent temperature as the warmth of the day increases, and which appears to take place more rapidly than the vapour might of itself make its way if the air were tranquil. M. Kreil remarks (Mag. und Met. Beob. Erster Jahrgang, p. 140), that in the summer months, when from the increased amount of the vapour its effects are more noticeable, the clearness of the sky decreases from the commencement of the morning to about noon, and then increases uninterruptedly till towards midnight. And M. Dove notices (Met. Untersuchungen, p. 53), that on fine calm days, when there is little lateral wind to disturb the ascending current, the clear morning becomes clouded towards noon; whilst towards evening, when the ascending current has ceased, these condensed vapours, no longer upborne by its influence, descend into the warmer strata and are redissolved: hence the peculiar transparency and beauty often observed in evening views.

Synopsis of the Annual Variations at Toronto.

Month.	Temperature.	Vapour pressure.	Gaseous pressure.
	°	in.	in.
January	26·7	·132	29·454
February	25·6 Min.	·123 Min.	29·396
March	32·1	·146	29·501 Max.
April	41·6	·186	29·398
May	50·5	·241	29·324
June	61·3	·399	29·165 Min.
July	65·1 } Max.	·443	29·194
August	65·1	·486 Max.	29·219
September	58·5	·402	29·232
October	43·3	·232	29·407
November	35·5	·179	29·413
December	27·3	·138	29·488

The Plates which are annexed exhibit—Plate XXI. the *Diurnal variation*, projected in curves, of the temperature, tension of vapour, gaseous pressure, and force of the wind. In each case the whole variation, *i. e.* the difference between the highest and lowest observation in the twenty-four hours, has been made equal to 1½ inch, and the proportionate amount has been laid off at each hour of observation: the scales are of course wholly arbitrary.

Plate XXII. The *Annual variation*, projected in curves, of the temperature, tension of vapour, and gaseous pressure. The whole variation of each has here also been made equal to 1½ inch, without reference to absolute values or to the scales employed in projecting the diurnal variations.

Plate XXIII. represents, on a scale of four inches to one-tenth of an inch, the diurnal variations of the barometer and gaseous pressure, projected in curves, and connected at each observation hour by vertical lines proportioned to the elastic force of the vapour. This Plate is illustrative of the conversion of the single progression of the gaseous pressure, into the double progression of the barometric pressure, by the presence and influence of the vapour pressure. The detached curve is that of the diurnal march of the temperature, and is inverted, for the purpose of showing more distinctly its correspondence with the curve of gaseous pressure.

An inference of much practical utility to general observers may be drawn from meteorological observations, made with the frequency which can only be expected at those observatories, where a sufficient establishment is maintained for the express purpose of observation. We may find that comparatively a very few observations in each day, at hours not inconvenient in ordinary life, may furnish a very close approximation to the mean values and to the annual and diurnal march of the atmospherical phænomena. Thus from the complete record at Toronto we find, as shown in the subjoined table, that the mean values of the temperature, of the vapour tension and of the humidity, of the pressure of the gaseous atmosphere, and of the whole atmospheric pressure, may all be obtained, with a very near approximation, by a single observation at 8 P.M. (mean time), provided the observation be made with tolerable precision in regard to the hour. By combining with this an observation about sunrise, and another between 2 and 4 in the afternoon, the maximum and minimum of the temperature, of the aqueous and gaseous pressure, and of the humidity, may also be obtained. These hours are by no means inconvenient for persons whose avocations permit them to keep a register at all; and appear in every way preferable to a selection which makes 3 o'clock in the morning one of the observation hours. That hour is perhaps the most generally inconvenient for the purpose of the whole twenty-four. The hours here suggested must not however be understood to be of universal application: they are not so thoroughly suitable, for example, at stations where, as at Trevandrum, the vapour pressure attains a maximum in the forenoon.

Convenient hours of observation.

For mean values, 8 P.M. mean time (precise); which at Toronto gives the following approximation: viz.—

At 8 P.M. at Toronto.	Temperature........	44°·1	Mean annual value		44°·4
	Humidity	78·5	"	"	78·0
	Vapour tension	·257	"	"	·259
	Barometric pressure ..	29·605	"	"	29·608
	Gaseous pressure	29·345	"	"	29·349

For maxima and minima.

From 4 to 6 A.M., for minimum of temperature and tension of vapour, and for maximum of humidity and gaseous pressure.

From 2 to 4 P.M., for maximum of temperature and tension of vapour, and for minimum of humidity and gaseous pressure.

I have now only to apologize to the Section for the length of time that I have occupied them, and to thank them for their patient attention.

York, September 27th, 1844.

Postscript, Woolwich, Nov. 30.

After the preceding pages were printed, I received from Mr. Airy the volume of the Greenwich magnetical and meteorological observations for 1842, in which the meteorological reductions have been made in almost exactly the same form as those of Toronto. The volume was accompanied by a suggestion from the Astronomer Royal, that it might increase the interest of this communication, if I were to add a few words by way of appendix, showing the points of similarity or dissimilarity in the results at the two stations. I have much pleasure in adopting this suggestion, and in availing myself of Mr. Airy's permission to do so; for I have had great satisfaction in noticing the very remarkable similarity which prevails in the results at Greenwich and Toronto, with reference to several points which have been the objects of especial notice in the preceding discussion. In the diurnal variations of the elastic force of the vapour,—of the gaseous pressure,—and of the force of the wind,—the evidence of a direct dependence on the diurnal march of the temperature is fully as striking at Greenwich as at Toronto, as will be seen by the following synopsis:

Synopsis of the Diurnal Variations at Greenwich.

Observation hours.	Barometer.	Thermometer.	Vapour pressure.	Gaseous pressure.	Force of the wind.
h m	in.	°	in.	in.	Sums of the estimated forces.
1 20 A.M.	29·826	45·4	·307	29·519	97½
3 20 A.M.	·822	44·9 Min.	·302 Min.	·520 Max.	93¼
5 20 A.M.	·824	45·0	·307	·517	89½
7 20 A.M.	·835	47·2	·321	·514	89 Min.
9 20 A.M.	·846	51·0	·335	·511	106½
11 20 A.M.	·845	54·1	·347	·498	117¾
1 20 P.M.	·832	55·7 Max.	·349 Max.	·483	131¼ Max.
3 20 P.M.	·823	55·0	·348	·475 Min.	129
5 20 P.M.	·823	52·8	·338	·485	120¾
7 20 P.M.	·830	49·8	·330	·500	109¾
9 20 P.M.	·838	47·8	·321	·517	102
11 20 P.M.	·836	46·3	·315	·521 Max.	95
Means of the Year.	29·832	49·6	·326	29·506	

At Greenwich the force of the wind is estimated at each observation hour in numbers varying within the limits of 0 to 6. At Toronto the estimation is in lbs. pressure on a square foot of surface kept perpendicular to the current. In single instances the scales are comparable, because the square of the number expressing the force at Greenwich corresponds approximately to the pressure in lbs. avoirdupois. But the comparability of the scales does not hold good when the sums of the forces and the sums of the pressures are taken. The sums of each are however comparable *inter se*, and show the hours of maximum and minimum force, and the regularity of the progression. The registry of the anemometer at Greenwich shows that the pressure of the wind is more than doubled in its mean diurnal range.

The following table exhibits the differences at the several observation hours of Greenwich and Toronto, of the temperature, of the vapour pressure, and of the gaseous pressure, from their respective mean yearly values. The sign + signifies above the mean value of the year, and — below it.

Observation hour.		Temperature.		Vapour pressure.		Gaseous pressure.	
Greenwich.	Toronto.	Greenwich.	Toronto.	Greenwich.	Toronto.	Greenwich.	Toronto.
h. m.	h.	°	°	in.	in.	in.	in.
1 20 A.M.	2 A.M.	−4·2	−4·6	−·019	−·021	+·013	+·013
3 20 A.M.	4 A.M.	−4·7	−5·2	−·024	−·025	+·014	+·019
5 20 A.M.	6 A.M.	−4·6	−5·0	−·019	−·017	+·011	+·027
7 20 A.M.	8 A.M.	−2·4	−1·8	−·005	+·001	+·008	+·023
9 20 A.M.	10 A.M.	+1·4	+1·9	+·009	+·011	+·005	+·015
11 20 A.M.	Noon.	+4·5	+4·5	+·021	+·023	−·008	−·017
1 20 P.M.	2 P.M.	+6·1	+6·1	+·023	+·026	−·023	−·040
3 20 P.M.	4 P.M.	+5·4	+6·1	+·022	+·021	−·031	−·039
5 20 P.M.	6 P.M.	+3·2	+3·7	+·012	+·010	−·021	−·022
7 20 P.M.	8 P.M.	+0·2	−0·3	+·004	−·002	−·006	−·001
9 20 P.M.	10 P.M.	−1·8	−2·3	−·005	−·009	+·001	+·009
11 20 P.M.	Midnight.	−3·3	−3·6	−·011	−·016	+·015	+·009

The mean *monthly* values of the vapour pressure, and of the gaseous pressure at Greenwich exhibit also the same correspondence with the variation of the temperature in the different months of the year as at Toronto.

Synopsis of the Annual Variation of the Temperature, Vapour pressure, and Gaseous pressure at Greenwich.

Month.	Temperature.	Vapour pressure.	Gaseous pressure.	Vapour pressure + or −, *i. e.* greater or less, than the mean annual pressure.	Gaseous pressure + or −, *i. e.* greater or less, than the mean annual pressure.
	°	in.	in.	in.	in.
January ...	32·9 Min.	·186 Min.	29·715 Max.	−·140	+·209
February...	40·8	·250	·626	−·076	+·120
March......	44·9	·272	·475	−·054	−·031
April	45·2	·248	·606	−·078	+·160
May	53·2	·334	·448	+·008	−·058
June	62·9	·433	·468	+·107	−·038
July	60·2	·416	·404	+·179	−·102
August ...	65·4 Max.	·505 Max.	·364	+·095	−·142
September.	56·4	·421	·294 Min.	−·038	−·212
October ...	45·4	·288	·561	−·058	+·055
November .	42·8	·268	·331	−·031	−·175
December .	45·0	·295	·712	....	+·206
Mean of the Year.	49·6	·326	29·506		

It appears therefore that the annual and diurnal variations derived from the observations at Greenwich present a most satisfactory accordance with those at Toronto in those points which were brought most prominently before the Association at York, and to which the attention of the Section was especially called, viz.—

First, in regard to the diurnal variation:

1. The vapour tension and the force of the wind have each a minimum, and the gaseous pressure a maximum, at or near the coldest hour of the day.
2. The vapour tension and the force of the wind have each a maximum, and the gaseous pressure a minimum, at or near the warmest hour of the day.
3. The diurnal march of each from the minimum to the maximum, and from the maximum to the minimum again, is continuous, like that of the temperature, without any interruption deserving of the name.
4. At Greenwich as well as at Toronto the diurnal variations of the vapour tension and of the gaseous pressure, produce by their combination the double maxima and minima of the diurnal oscillation of the mercury in the barometer.

Secondly, in respect to the annual variation:

The annual march is somewhat less regular at Greenwich than at Toronto, being derived from the observations of a single year only; but we have the same general features: a minimum of temperature and vapour-pressure, and a maximum of gaseous pressure in the midwinter; and a maximum of temperature and vapour pressure, and a minimum of gaseous pressure in the midsummer. All the summer months are characterised by the + sign in the vapour, and by the — in the gaseous pressure; and all the winter months by the — sign in the vapour, and the + sign in the gaseous pressure.

I am unable at the present moment to pursue the comparison of the Greenwich and Toronto results in many other points in which I can perceive that the interest would prove an ample repayment for the time so employed. But I may hope to enjoy some future occasion of resuming the subject under more favourable circumstances in respect to leisure than I can at present command.

Report on some recent Researches into the Structure, Functions and Œconomy of the Araneidea *made in Great Britain. By* JOHN BLACKWALL, *F.L.S.*

IN essaying to give an epitome of some investigations recently made in this country relative to the organization, physiology and œconomy of the *Araneidea*, I shall endeavour to accomplish the undertaking in as compendious a manner as may be deemed compatible with a perspicuous statement of the various facts to be detailed, distinguishing those already before the public from such as are not by references to the works in which they have appeared.

Without further preface, I proceed to the consideration of those remarkable appendages termed *scopulæ* or brushes, with which the tarsi of numerous species of spiders are provided. This apparatus, consisting of coarse, compound, hair-like papillæ either distributed along the inferior surface of the tarsi or situated immediately below the claws at their extremity, bears a close analogy to the tarsal cushions of insects, enabling its possessor to ascend the perpendicular surfaces of highly polished bodies and even to adhere to smooth objects in an inverted position by the emission of a viscous secretion*. The different plans according to which the papillæ are disposed upon the tarsi are respectively represented by two common British spiders, *Drassus sericeus* and *Salticus scenicus*.

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[*] Transactions of the Linnæan Society, vol. xvi. pp. 768, 769. Researches in Zoology, p. 289.

Some of the spiders belonging to the families *Theridiidæ* and *Epëiridæ* have the sides and lower part of the tarsi, at their extremity, supplied with several small, curved, dentated claws, in addition to the three larger ones common to them all. *Epëira quadrata, Epëira apoclisa,* and, indeed, most of the larger species of *Epëiræ* indigenous to Great Britain, exhibit this structure to advantage under the microscope; they have, besides, a strong, moveable spine, inserted near the termination of the tarsus of each posterior leg, on the under side, which curves a little upwards at its extremity, and presents a slight irregularity of outline at its superior surface. These spines, which have been denominated *sustentacula,* subserve an important purpose. By the contraction of their flexor muscles they are drawn towards the foot, and are thus brought into direct opposition to the claws, by which means the animals are enabled to hold with a firm grasp such lines as they have occasion to draw from the spinners with the feet of the hind-legs, and such also as they design to attach themselves to*.

There are on the superior part of the metatarsus of the posterior legs of all the *Ciniflonidæ* two parallel rows of moveable spines commencing just below its articulation with the tibia and terminating near its lower extremity. In a state of repose, the spines composing both rows are directed down the joint and are somewhat inclined towards each other; those of the upper row have a considerable degree of curvature and taper gradually to a fine point, those of the lower row being stronger, more closely set, and less curved. Employed to transform, by the process of curling, certain lines proceeding from the spinners into the small flocculi characteristic of the snares of the *Ciniflonidæ,* the double series of spines has received the name of *calamistrum.*

When a spider of this family purposes to form a flocculus, it presses its spinners against one of the glossy lines constituting the foundation of its snare, and, emitting from them a small quantity of liquid gum, attaches to it several slender filaments, drawn out by advancing the abdomen a little, and kept distinct by extending the spinning mammulæ laterally. The posterior legs are then raised above the plane of position, and the tarsal claws of one of them are applied to the superior surface of the metatarsus of the other, near its articulation with the tarsus, and the *calamistrum* is brought immediately beneath the spinners, at right angles with the line of the abdomen. By a slight extension of the joints of the posterior legs the *calamistrum* is directed backwards across the diverging extremities of the spinners, which it touches in its transit, and is restored to its former position by a corresponding degree of contraction in the joints. In proportion to the continuation of this process the inflected lines of the flocculus are produced, the spider making room for them as they accumulate by elevating and at the same time advancing the abdomen a little, which it effects by slightly extending the joints of the third pair of legs and contracting those of the first and second pairs. When the requisite quantity of inflected filaments is obtained, the spider again applies its spinners to one of the glossy lines and attaches the flocculus to it. In this manner it proceeds with its labours, occasionally employing both *calamistra,* till the snare is completed. The *modus operandi* appears to be this. The points of the lower row of spines in passing over the extremities of the spinners draw from them lines which run into numerous flexures in consequence of not being kept fully extended, and the purpose subserved by the spines of the upper row is the detachment of these lines from the spines of the lower row by a motion upwards†.

If the metatarsus of one of the posterior legs of *Ciniflo ferox,* a spider of

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* Transactions of the Linnæan Society, vol. xvi. p. 476; vol. xviii. p. 224, note*.

† Ibid. pp. 471–475; vol. xviii. pp. 224, 606.

frequent occurrence in the interior of buildings, be examined under the microscope with a moderately high magnifying power, the arrangement of the spines composing the two rows which constitute the *calamistrum* will be apparent.

Four, six, or eight mammulæ, somewhat conical or cylindrical in figure, and composed of one or more joints each, constitute the external spinning apparatus of the *Araneidea*: they are usually closely grouped in pairs at the extremity of the abdomen, and are readily distinguished from each other by their relative positions. The pair situated nearest to the anus may be denominated the superior spinners; that furthest removed from the anus, the inferior spinners; and the mammulæ placed between these extremes, the intermediate spinners; distinguishing them, when there are two pairs, by prefixing the terms superior and inferior. Exceedingly fine, moveable papillæ or spinning tubes, for the most part dilated at the base, occur at the extremity of the mammulæ, or are disposed along the inferior surface of their terminal joint, whence issues the viscous secretion of which all the silken lines produced by spiders are formed. The papillæ connected with the mammulæ vary greatly in number in different species of spiders, and also differ considerably in size, not only in individuals of the same species, but often even on the same mammulæ.

Among our native spiders, the larger species of *Epëiræ* have the mammulæ most amply provided with papillæ; it is probable, however, that the total number does not greatly exceed a thousand even in adult females of *Epëira quadrata*, whose weight is about twenty grains, and in many other species it is much smaller. In *Tegenaria civilis* the total number of papillæ does not amount to four hundred; in *Textrix lycosina* and *Clubiona corticalis* it is below three hundred; in *Segestria senoculata* it scarcely exceeds one hundred; and in many of the smaller spiders it is still further reduced.

A difference in the number and size of the papillæ connected with the several pairs of mammulæ in the same species, and with similar pairs in different species, is also very apparent. In spiders of the genera *Epëira*, *Tetragnatha*, *Linyphia*, *Theridion* and *Segestria*, they are generally much more numerous and minute on the inferior spinners than on the superior and intermediate ones; the last are the most sparingly supplied with them, and in the case of *Segestria senoculata* each has only three large papillæ at its extremity. An arrangement nearly the reverse of this takes place in some of the *Drassi*, and is conspicuous in *Drassus ater*, which has the intermediate spinners abundantly furnished with papillæ, those on the inferior spinners being very few in number and chiefly of large dimensions, emitting the viscous secretion copiously. The papillæ connected with the short terminal joint of each inferior spinner of this species vary in number with the age of the animal; the young, on quitting the cocoon, are provided with four only; individuals which have attained nearly a third of their growth have five or six; those about two-thirds grown, six or seven; and adults, which have acquired their full complement, eight; two of them, situated on the inferior surface of the spinner, at a greater distance from its extremity than the rest, are minute and almost contiguous. It is a fact deserving of notice, that the papillæ are not always developed simultaneously on these spinners, six, seven, or eight being sometimes observed on one, when five, six, or seven only are to be seen on the other; and this remark is applicable, not to the inferior spinners alone, but to the intermediate ones also, which, in mature individuals, are further modified by having the extremities of the terminal joints directed downwards at right angles to their bases. The same law of development holds good as regards the papillæ connected with the inferior spinners of *Drassus cupreus* and *Drassus sericeus*, and though their number is not uniformly the same even in adults of either of these or the preceding species, yet the two minute ones belonging to each mammula are present invariably *.

The superior spinners of many spiders are triarticulate; and when the terminal joint is considerably elongated, thickly clothed with hairs, and tapers to a point, the papillæ, in the form of hair-like tubes dilated at the base, are commonly distributed along its inferior surface, as in the case of *Agelena labyrinthica, Tegenaria domestica,* and *Textrix lycosina.* This deviation from the prevailing structure has induced Lyonnet, Savigny, Treviranus, Audouin, and other skilful zootomists, who have failed to detect the papillæ, to regard the superior mammulæ, thus modified, as anal palpi, and to deny that they perform the office of spinners; but if these parts be carefully examined with a powerful magnifier in living specimens during the exercise of their function, the fine lines of silk proceeding from the papillæ cannot fail to be discerned, and a correct knowledge of their external organization may thus be obtained. Not being aware, apparently, of the publication of this discovery in the 'Report of the Third Meeting of the British Association for the Advancement of Science, held at Cambridge in 1833,' p. 445, Baron Walckenaer, in the Supplement to the second volume of his 'Histoire Naturelle des Insectes Aptères,' p. 407, has ascribed it to M. Dugès, whose observations on the subject in the 'Annales des Sciences Naturelles,' seconde série, t. vi., Zoologie, p. 166, were not published till 1836.

One of the most striking peculiarities in the structure of the *Ciniflonidæ,* which serves to distinguish them from all other animals of the order *Araneidea* at present known, is the possession of a fourth pair of spinners. These spinners are shorter and further removed from the anus than the rest, being situated at the base of the inferior intermediate pair, by which they are almost concealed when in a state of repose. Their figure is somewhat conical, but compressed and truncated, so that the base and apex are elliptical with long transverse axes. Consisting of a single joint only, each is connected with the other throughout its entire length, the extremity alone being densely covered with exceedingly minute papillæ, which emit the viscous matter that is formed by the *calamistra* into a delicate tortuous band constituting a portion of every flocculus in the snares of these spiders, and chiefly imparting to them their most important property, that of adhesion †.

Arachnologists have not bestowed that degree of attention on the palpi of spiders to which their diversified structure and important functions undoubtedly entitle them.

Much difference is observable in the relative proportions of the several joints of the palpi of female spiders, not only in species constituting the same family, but even in those belonging to the same genus; while, on the other hand, it frequently happens that females belonging to different genera bear a striking resemblance to each other in this particular. It is among male spiders, however, that these peculiarities are the most marked, and to them may be added structural differences and resemblances both of the palpi and sexual organs still more conspicuous.

A great similarity in the form of the organs of reproduction, in the simplicity of their structure, and in the manner of their connexion with the digital joint of the palpi, which has no cavity opening externally, may be seen in certain males of the family *Dysderidæ*; in *Dysdera erythrina, Dysdera hombergii, Segestria perfida, Segestria senoculata,* and *Oonops pulcher,* for example; and this similitude is extended to the males of various species belonging to the family *Mygalidæ.*

Between the males of *Pachygnatha clerckii* and *Tetragnatha extensa* there

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* Transactions of the Linnæan Society, vol. xviii. p. 219–224.

† Ibid. pp. 223, 224, 606.

is a near approximation in the structure of the palpi and sexual organs, yet these spiders are not included in the same family, the former belonging to the *Theridiidæ,* and the latter to the *Epëiridæ.*

If the spiders constituting the genus *Clubiona* be compared with those of the genus *Drassus,* and those of the genus *Linyphia* with the species comprised in the genus *Neriëne*; or, extending the investigation still further, if the genera *Walckenaëra, Theridion, Epëira, Eresus, Salticus, Thomisus,* and *Philodromus* be compared together, numerous instances of correspondence in the relative proportions of the joints of the palpi will be perceived immediately; at the same time, striking contrasts will present themselves to the eye of the observer, not as regards proportion alone, but organization also, even among nearly allied species.

As the full development of the palpi and the organs of generation connected with them indicates a state of maturity in male spiders, the skilful arachnologist is enabled, by attending to this circumstance, not only to distinguish adult males from females, but likewise from immature individuals of both sexes. This knowledge is useful in preventing him from falling into the too common error of mistaking young spiders for old ones, and of describing them, and the sexes of spiders of the same kind, as distinct species. When any doubts exist as to the specific identity of adult spiders of different sexes, they frequently may be set at rest by placing the spiders together in captivity and noticing whether they pair or not.

The great diversity of structure observable in the palpi and sexual organs of male spiders supplies excellent specific characters, and, indeed, frequently presents the only available means of distinguishing species of similar colours and dimensions from each other; but when it is borne in mind that this diversity of structure extends to spiders connected by the closest relations of affinity, it is, perhaps, in vain to expect that it will ever be applied with much success to the establishment of genera.

From remarks on the structure of the palpi to the consideration of the functions they perform the transition is easy and natural.

Many spiders employ their palpi in assisting to collect the slack line which results from their operations when engaged in ascending the silken filaments by which they have lowered themselves from stations previously occupied, or in drawing in such as have been emitted from the spinners for the purpose of facilitating a change of situation in some other direction. The silk collected on these occasions is formed into a small heap, which is either attached to some fixed object, or is transferred to the maxillæ, and, after having been mixed with saliva and reduced in volume by repeated acts of compression, is ultimately allowed to fall to the ground.

In conjunction with the mandibles, the palpi are employed by females of the species *Dolomedes mirabilis* and *Dolomedes fimbriatus* to retain their cocoons under the sternum, in which situation those spiders usually carry them wherever they move. The *Lycosæ* also avail themselves of the same parts in regaining possession of their cocoons when detached from the spinners.

Certain spiders belonging to the genus *Mygale* have the inferior part of the tarsi furnished with a dense brush of hair-like papillæ for the emission of a viscous secretion, which enables them to ascend bodies having smooth perpendicular surfaces. Now, as the females of these species usually have the under side of the digital joint of their palpi, which are remarkably long and powerful, supplied in like manner with papillæ, analogy would lead to the conclusion that, in harmony with their organization and distribution, they also constitute a climbing apparatus.

Various species of *Salticidæ,* to which distinctness and accuracy of vision are of the utmost consequence, as they do not construct snares, but capture their prey by springing suddenly upon it from a distance, have the terminal joint of the palpi abundantly supplied with hairs, and constantly make use of those organs as brushes to remove dust, or any other extraneous matter, from the corneous coat of the anterior eyes.

The palpi appear to afford direct assistance likewise to spiders in general in securing their prey, in changing its position while they are feeding upon it, and in restraining the action of the wings of all their victims which happen to be provided with them*.

With regard to the function exercised by the remarkable organs connected with the digital joint of the palpi of male spiders there exists some difference of opinion. Taking anatomy as his guide, Treviranus arrived at the conclusion that the parts in question are used for the purpose of excitation merely, preparatory to the actual union of the sexes by means of appropriate organs situated near the anterior part of the inferior region of the abdomen. This view of the subject, which is very generally adopted, is opposed to that derived from physiological facts by Dr Lister and the earlier systematic writers on arachnology, who regarded the palpal organs as strictly sexual.

Rejecting the opinion of Treviranus, Baron Walckenaer has given his support to that entertained by Lister and the physiologists, having endeavoured to establish its accuracy by pursuing the imperfect method of investigation employed by the latter, which chiefly consists in examining the condition of the palpal organs when applied by male spiders to the vulva of females and carefully noticing the changes they undergo; but as it is possible that such females, should they prove to be prolific, may have been impregnated at a former period, and as other organs than those connected with the digital joint of the palpi may have been instrumental in producing the result, observations of this description appear to be quite inadequate to effect the object proposed.

An attempt to relieve the inquiry from objections so weighty is recorded in the 'Report of the Third Meeting of the British Association for the Advancement of Science, held at Cambridge in 1833,' pp. 444–5, and the result arrived at has a direct tendency to confirm the truth of the opinion promulgated by Dr. Lister. Since that time, researches in connexion with this subject have been greatly extended and varied, and it is satisfactory to add, that they supply a body of evidence which appears to be conclusive as to the agency of the palpal organs.

The following is a concise summary of the more important particulars elicited by this investigation.

It is an admitted fact, that female *Aphides*, when impregnated, are capable of producing females which, without sexual intercourse, are prolific through several successive generations. In order to determine whether this is the case with spiders or not, young females of the species *Tegenaria domestica, Tegenaria civilis, Agelena labyrinthica, Ciniflo atrox, Drassus sericeus, Theridion quadripunctatum, Segestria senoculata*, &c., were placed in phials of transparent glass and fed with insects. Most of these individuals remained in captivity from one to three years after they had completed their moulting and attained maturity; yet three only, an *Agelena labyrinthica*, a *Tegenaria domestica*, and a *Tegenaria civilis*, produced eggs, and they proved to be sterile, though several of the others, to which adult males were subsequently introduced, laid prolific eggs after coition. It is worthy of remark, that the spiders which produced unfruitful eggs deposited them in cocoons and bestowed the same care upon them as if they had been fertile.

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* Report of the Twelfth Meeting of the British Association for the Advancement of Science, held at Manchester in 1842; Transactions of the Sections, pp. 67, 68.

This preliminary point being settled, attention was directed in the next place to spiders in a state of liberty, when it was perceived that the males of various species do not bring any part of the abdomen near the vulva of the females in the act of copulation, and that this is the case with the *Lycosæ* in particular; for example, the male of *Lycosa lugubris*, after having made the customary advances, springs suddenly upon the back of the female with his head directed towards her spinners and the anterior part of the inferior surface of the abdomen resting upon her cephalothorax; then placing the first pair of legs immediately behind her posterior pair, the second pair between her second and third pairs, the third pair between her first and second pairs, and the posterior pair before her first pair, he thus embraces her, and applies the palpal organs to the vulva by inclining to one side or the other as the occasion may require. In this situation the male remains till the act of union is consummated and then quits it with precipitancy, so that his abdomen is not even brought into contact with that part, much less with the vulva, of the female.

Precisely the same manner of proceeding is pursued by *Lycosa agretyca*, *Lycosa saccata*, *Lycosa pallida*, and *Lycosa obscura*; and females of the last species have been seen to receive the embraces of several males in immediate succession, and to copulate even at the time they had cocoons containing newly-laid eggs attached to their spinners, which circumstances serve to support the opinion that some spiders pair oftener than once in the course of their lives.

When in captivity, the sexes of *Lycosa lugubris* sometimes continue paired more than four hours, during which period the male applies the palpal organs several hundred times to the vulva of the female.

Notwithstanding the important bearing of these observations upon the physiological problem under consideration, something was still wanting to complete its solution, and recourse was had to direct experiment to supply the desideratum.

On the 4th of May 1842, an adult male *Tegenaria civilis* was procured, and, being held by the legs in an inverted position, the inferior surface of the abdomen was moistened by applying to it a camel's hair pencil which had been dipped in water. The entire interval between the plates of the spiracles, supposed by Treviranus to be the seat of the sexual organs in male spiders, and even a considerable space below that interval, was then covered with strong, well-gummed writing-paper cut into a suitable form and closely applied, and when the paper became thoroughly dry and firmly attached, the spider was placed in a phial with a female of the same species, which had been in solitary confinement from the 2nd of June 1841, and had cast its skin twice during its captivity. With this female the male paired on the same day he was introduced to her, applying the palpal organs to the vulva in the usual manner, and immediately after the union was completed he was removed from her. On the 23rd of May she deposited a set of eggs in a cocoon spun for their reception, and on the 11th of June she constructed another cocoon in which she laid a second set of eggs. All these eggs proved to be prolific, the extrication of young spiders from the first set commencing on the 26th of June, and from the second set on the 13th of July, in the same year. Without renewing her intercourse with the male, this female deposited a set of eggs in a cocoon on the 2nd of April, the 9th of May, the 4th of June, the 22nd of June, and the 9th of July 1843, and on the 22nd of April, the 30th of May, the 29th of June, and the 1st of August 1844, respectively, nine sets in number, all of which produced young.

Another male *Tegenaria civilis*, after undergoing the same treatment exactly as that in the preceding experiment, was introduced, on the 6th of May 1842, to a female of its own species, which had been in solitary confinement from the 25th of January 1840, and had cast its skin three times during its captivity. This female received the embraces of the male as soon as he was admitted into the phial to her, and laid a set of eggs on the 27th of the same month, all of which were productive, the young beginning to be disengaged from them on the 27th of the ensuing month.

In stating a further repetition of this experiment with spiders of the same species, it is only necessary to premise that the female had cast her skin three times in captivity, and that the male had but the right palpus, the other having been removed by amputation. They were placed together on the 16th of May 1842, paired the same day, and were separated as soon as their union was accomplished. On the 19th of June the female deposited a set of eggs in a cocoon, which began to be hatched on the 24th of the following July, and all produced young. Without further sexual intercourse, in 1843 she enveloped a set of eggs in a cocoon on the 7th of April, the 5th of May, the 1st of June, the 18th of June, and the 3rd of July, respectively, from all which young were disengaged.

Promptness in accommodating itself to the restraint of confinement, together with the certainty of being able to procure specimens whenever they might be required, led to the selection of *Tegenaria civilis* as a suitable subject for the foregoing experiments, from which, conjointly with the preceding observations, the following inferences may be deduced:—

1st. That female spiders are incapable of producing prolific eggs without sexual intercourse.

2nd. That females which have not been impregnated occasionally produce sterile eggs.

3rd. That the female of *Tegenaria civilis*, when impregnated, is capable of producing several sets of prolific eggs in succession without renewing its intercourse with the male*, two years or more occasionally elapsing before all are deposited, and a period of ten months nearly intervening sometimes between the deposition of two consecutive sets.

4th. That spiders of various species copulate without the abdomen of the male being brought into contact with that of the female.

5th. That male spiders, in which the part stated by Treviranus to be the seat of the sexual organs is entirely covered with strong, well-gummed writing paper closely applied, nevertheless possess the power of exercising the function of generation unimpaired.

6th. Lastly, that males so circumstanced invariably consummate the act by applying the palpal organs to the vulva of females, plainly demonstrating thereby the interesting truth, that those organs, however anomalous their situation may be, are the only efficient instruments employed by male spiders in the propagation of their species.

Before they arrive at maturity spiders change their skin several times: the manner in which these moults are effected may be illustrated by describing the proceedings of an individual of the species *Epëira calophylla*. Preparatory to casting its integument, this spider spins some strong lines in the vicinity of its snare, from which it suspends itself by the feet and a filament proceeding from the spinners. After remaining for a short time in this situation, the coriaceous covering of the cephalothorax gives way laterally, disuniting at the insertion of the legs and mandibles; the line of separation pursues the same direction till it extends to the abdomen, which is next dis-

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* *Tegenaria domestica* (*Aranea domestica*, Linn.), *Agelena labyrinthica*, and *Epëira cucurbitina* are endowed with similar powers of production. *Vide* the Report of the Third Meeting of the British Association, p. 445.

engaged, the extrication of the legs being the last and greatest difficulty the spider has to evercome. As the suspensory filament connected with the spinners of the exuviæ is considerably shorter than the legs and does not undergo any sensible alteration in length, the abdomen, during the process of moulting, becomes gradually deflected from its original horizontal direction till it assumes a vertical position nearly at right angles with the cephalothorax. By this change of posture, attended with numerous contortions of the body, and alternate contractions and extensions of the limbs, the spider is ultimately enabled to accomplish its purpose. When it has completely disengaged itself from the slough, it remains, for a short period, in a state of great exhaustion, suspended solely by a thread from the spinners, connected with the interior of the abdominal portion of the cast skin, which is much corrugated. After reposing a little, the spider further attaches itself to the suspensory lines by the claws of the feet, and when its strength is sufficiently restored, and its limbs have required the requisite degree of firmness, it ascends its filaments and seeks its retreat*.

Recent observations establish the fact that the number of times spiders change their integument before they become adult is not uniformly the same as regards every species. A young female *Epëira calophylla*, disengaged from the egg on the 30th of March 1843, moulted on the 8th of the ensuing month in the cocoon, which it quitted on the 1st of May; moulting again, in the same year, on the 4th of June, the 22nd of June, the 12th of July, and the 4th of August, respectively, when it arrived at maturity, having cast its skin five times.

An egg of *Epëira diadema*, hatched on the 14th of April 1843, produced a female spider, which moulted in the cocoon on the 24th of the same month; on the 3rd of May it quitted the cocoon, and moulted again on the 21st of June, the 10th of July, the 3rd of August, and the 23rd of August, in the same year. On the 28th of February 1844 it died in a state of immaturity after having completed its fifth moult.

On the 27th of June 1842 an egg of *Tegenaria civilis* produced a female spider, which underwent its first moult in the cocoon on the 10th of the ensuing July; quitting the cocoon on the 21st of the same month, it moulted again on the 17th of August, the 4th of September, and the 26th of September, in the same year; and on the 26th of January, the 9th of April, the 24th of May, the 21st of June, and the 5th of August in 1843, when it arrived at maturity, having changed its integument nine times.

A male *Tegenaria civilis*, extricated from the egg on the 27th of June 1842, also moulted nine times, casting its skin in the cocoon on the 10th of the following July; on the 21st of the same month it abandoned the cocoon, moulting again on the 13th of August, the 10th of September, and the 13th of October, in the same year; and on the 1st of February, the 25th of April, the 17th of June, the 13th of July, and the 17th of October in 1843, when its development was complete.

Modifications of food and temperature exercise a decided influence upon the moulting of spiders. A young female *Tegenaria civilis* disengaged from the egg on the 24th of July 1842, on the 2nd of the following August moulted in the cocoon, which it quitted on the 12th of the same month, casting its skin again on the 29th of August, and the 10th of October, in the same year; being scantily supplied with nutriment, it increased very little in size, and died on the 4th of July 1843, having changed its integument three times only. Another female of the same species, which was extricated from the egg on the same day as the foregoing individual, and was well-fed, on the 13th

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* Transactions of the Linnæan Society, vol xvi. p. 482–484.

of July 1843 had moulted seven times. It is apparent also from the particulars already stated, that the intervals between consecutive moults are much shorter when the temperature of the atmosphere is high than when it is low.

Immature spiders infested by the larva of *Polysphincta carbonaria*, an insect belonging to the family *Ichneumonidæ*, which feeds upon their fluids, never change their integument*.

Like certain animals of the class *Crustacea*, spiders possess the property of reproducing such limbs as have been detached or mutilated, and this curious physiological phænomenon is intimately connected with the renovation of the integument, as it is observed to take place at the time of moulting only. Experiments illustrative of this interesting subject have been multiplied to a very great extent; in introducing some of them to notice, such have been selected, as from the novel and important conclusions deducible from them are best deserving of attention.

1. A young male *Textrix lycosina* had half of the terminal joint of each superior spinner amputated, and the posterior leg on the right side detached at the coxa, on the 3rd of August 1838. It moulted on the 10th of September, reproducing the detached parts, which were small but perfect in structure. On the 23rd of February 1839 it moulted again and became adult; at the same time a sensible increase took place in the bulk of the reproduced parts, which, nevertheless, were still defective in point of size.

2. On the 23rd of August 1838 a young female *Tegenaria civilis* had the anterior leg on the right side and the third leg on the left side detached at the coxa, the terminal joint of the superior and inferior spinners on the right side being amputated at the same time. This spider moulted on the 27th of September, when the detached parts, of a smaller size than the corresponding parts on the opposite side, but perfect in structure, were reproduced. On the 6th of November it changed its integument a second time, and on the 16th of June 1839 a third time, when it arrived at maturity. The reproduced parts advanced perceptibly in growth at each successive moult, but did not ultimately acquire their full dimensions.

3. A young male *Tegenaria civilis* had the digital joint of the left palpus, which was very tumid, detached on the 6th of October 1838. It moulted on the 17th of June 1839 and reproduced the left palpus, which, though small, had the radial joint provided with the apophysis characteristic of a state of maturity in this species. The sexual organs, however, were altogether wanting, and the digital joint was slightly modified in size and form by this circumstance. It is scarcely necessary to remark that the sexual organs connected with the right palpus were fully developed.

4. The digital joint of the left palpus of a young female *Segestria senoculata* was amputated on the 18th of May 1839. This spider cast its integument on the 8th of July, the left palpus, of a small size, being reproduced. It moulted again on the 28th of June 1840, when the reproduced palpus had its dimensions enlarged and the spider arrived at maturity. On the 12th of December 1842 it died, having existed nearly three years and a half in captivity.

5. On the 8th of June 1839 a young female *Agelena labyrinthica* had the terminal joint of each superior spinner amputated. Bringing the extremities of the tarsi of the posterior legs to the mouth, it moistened them with saliva, and repeatedly applied them to the mutilated parts. On the 21st of the same month it moulted, and the superior spinners, of a small size, were reproduced. It moulted again on the 12th of the ensuing July, when the reproduced spinners were increased in size, and it arrived at maturity.

6. A young male *Textrix lycosina* had the terminal joint of each superior

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* Annals and Magazine of Natural History, vol. xi. p. 1–4.

spinner amputated, and the third leg on the right side detached at the coxa, on the 25th of July 1839. This spider cast its integument on the 6th of the ensuing August, when the stumps only of the mutilated parts were produced. On the 2nd of December, in the same year, it moulted again; the superior spinners and third leg on the right side, of a small size, were then reproduced, and it arrived at maturity.

7. The left palpus of a young male *Tegenaria civilis*, the digital joint of which was very tumid, was amputated at the axillary joint on the 15th of January 1840. On the 22nd of June, in the same year, it moulted, reproducing the left palpus, which was of small dimensions. The radial joint was provided with an apophysis, indicating the mature state of the spider, but the digital joint was somewhat modified in size and form, and the sexual organs were not reproduced.

8. A young male *Tegenaria civilis* had the right palpus amputated at the axillary joint on the 15th of January 1840. It moulted on the 2nd of the following June, when the detached part, of a small size, was reproduced and the digital joint became very tumid. On the 12th of August, in the same year, it moulted again; the right palpus was augmented in size, the radial joint was furnished with an apophysis, and the sexual organs, complete in their organization, were developed; these several parts, however, were still decidedly smaller than the corresponding parts of the left palpus.

9. On the 25th of January 1840 the left palpus of a young female *Tegenaria civilis* was amputated at the axillary joint. This spider moulted on the 1st of the ensuing May, at which time the detached part, of a small size, was reproduced. On the 20th of June and the 6th of August, in the same year, it moulted again and arrived at maturity, the left palpus receiving an increase in size at each successive moult.

10. A young male *Ciniflo ferox* had the cubital, radial and digital joints of the left palpus amputated on the 26th of May 1840. It moulted on the 18th of the following June and reproduced the left palpus, which was small, with the digital joint very tumid. On the 8th of August, in the same year, it moulted again, when the left palpus was enlarged, the apophyses of the radial joint were produced, and the sexual organs were developed. Though the several parts of the left palpus were smaller than the corresponding parts of the right palpus, yet they were perfect in their organization.

11. The left palpus of a young male *Ciniflo atrox* was amputated at the axillary joint on the 28th of May 1840. This spider changed its integument on the 27th of the following June, and reproduced the left palpus, which had the digital joint very tumid. On the 11th of August, in the same year, it moulted again, when the apophyses of the radial joint and the sexual organs, perfect in structure, were developed, but all the parts of the left palpus were smaller than the corresponding parts of the right palpus.

12. A young male *Linyphia cauta* had the right palpus at the axillary joint, the cubital, radial and digital joints of the left palpus, and the tibiæ and tarsi of the first, second and third legs on the left side amputated on the 30th of May 1840. On the 25th of the ensuing June it moulted, when the stumps only of the palpi were produced, but the mutilated legs, of small dimensions, were reproduced. It moulted again on the 21st of July, in the same year, and though the palpi still were not reproduced, yet the newly-formed legs were augmented in size and the spider arrived at maturity.

13. The digital joint of the left palpus of a young male *Linyphia cauta*, which was very tumid, was amputated on the 20th of July 1840. The spider moulted on the 19th of the following August, reproduced the left palpus, of a small size, with the digital joint considerably modified, and at the same time arrived at maturity; but the sexual organs were not reproduced.

14. A young male *Tegenaria civilis* had the right palpus amputated at the axillary joint on the 9th of June 1841. On the 13th of the following July it cast its integument and reproduced the right palpus, which, though small, had the digital joint very tumid. It moulted again on the 20th of August, in the same year, when the dimensions of the right palpus were augmented, the radial joint was provided with an apophysis, and the sexual organs were developed. The organization of the right palpus was perfect in all its parts, but they were smaller than the corresponding parts of the left palpus.

15. On the 25th of June 1841 a young male *Drassus sericeus* had the cubital, radial and digital joints of the left palpus amputated, the digital joint being very tumid. It moulted on the 16th of the ensuing August and reproduced the left palpus, of a small size; the radial joint was provided with an apophysis, indicating the mature state of the spider, but the sexual organs were not reproduced.

16. A young male *Ciniflo ferox* had the right palpus amputated at the axillary joint on the 2nd of July 1841. On the 19th it moulted, but the stump only of the mutilated part was produced. On the 28th of the same month the left palpus was amputated at the axillary joint. The spider moulted again on the 28th of the ensuing August, when both the palpi, of a small size, were produced.

17. The anterior leg on the left side of a young female *Tegenaria civilis* was amputated at the coxa on the 1st of September 1842. This spider was dissected on the 14th of the following October, when on the point of moulting, as was evident from the deepened hue of the integument and from the perfect structure of the tarsal and palpal claws, visible through it. The anterior leg on the left side, which was reproduced, was complete in its organization, $\frac{7}{24}$ths of an inch in length, and was curiously folded in the integument of the old coxa, which measured only $\frac{1}{24}$th of an inch in length.

18. A young male *Tegenaria civilis* had the posterior leg on the left side amputated near the middle of the tibia on the 24th of April 1843, when it moistened the tarsus of the third leg on the same side with saliva and repeatedly applied it to the mutilated limb. Being about to moult, this spider was dissected on the 5th of the ensuing June; the posterior leg on the left side, which was reproduced, was found to have its tarsal and metatarsal joints folded in the undetached half of the integument of the old tibia.

A recapitulation of the more remarkable results obtained from the experiments, elucidated in several instances by additional facts and observations, will not, it is presumed, be deemed superfluous.

Physiologists, in conducting researches relative to the reproduction of the limbs of spiders, seem to have limited their investigations to the legs of those animals; whereas, in the experiments detailed above, the palpi and spinners, as well as the legs, were operated upon; and all these parts are found to be renewed, and afterwards to have their dimensions enlarged at the period of moulting only; it appears also that if a part of a limb be amputated, as the tarsus of a leg or the digital joint of a palpus, the whole is reproduced, all the joints of the new limb, though small, being proportionate to those of the corresponding limb on the opposite side, with the exception of the digital joint of the palpi of male spiders when the sexual organs are not reproduced, which is usually somewhat modified in size and form by that circumstance.

At the penultimate moult of male spiders the digital joints of the palpi become very tumid, in much the greater number of species, by a sudden and rapid advance towards development in the sexual organs, and should those parts be detached during the interval which elapses between that and the succeeding moult, though the palpi, indicating by their organization that the animal has arrived at maturity, may be reproduced, yet the sexual organs are always absent. (See experiments 3, 7, 13, 15.) Adult males of the species *Lycosa obscura*, *Dysdera hombergii*, and *Philodromus dispar* have been found in a state of liberty with the palpi unequal in size and the smaller one entirely destitute of the sexual organs.

When the palpi of male spiders, which had been amputated before the penultimate moult, are reproduced, the sexual organs, perfect in structure, are reproduced also (see experiments 8, 10, 11, 14); unexceptionable evidence in support of this singular fact is to be found in their reduced dimensions and integrity of form, but it will scarcely be denied that the original germs of those organs must have been removed with the detached palpi. That the function of the sexual organs is not in the least affected by their reproduction there exists the most satisfactory proof. In the last of those experiments, having for their object the determination of the seat of the sexual organs in male spiders, recorded in this report, the male *Tegenaria civilis*, stated to have possessed the right palpus only when introduced to the female, is identical with that which was the subject of experiment 8 in the foregoing series; consequently, its sexual organs had been reproduced, yet the fertility of its mate bore ample testimony to the unimpaired efficiency of their generative agency.

If experiments 6 and 16 be referred to, it will be seen that the stumps only of mutilated parts are occasionally produced at the following moult, and that the entire parts, of a small size, are sometimes restored at a subsequent moult.

Experiment 12 presents an extraordinary case of the stumps of the palpi being produced at two consecutive moults after they had suffered mutilation, though several legs of the same spider, mutilated at the same time, were renewed at the next moult after the infliction of the injury.

The fact, that reproduced legs, immediately antecedent to the process of moulting, are folded in the integument of the undetached portion of the mutilated limbs, is clearly established by experiments 17 and 18.

With some spiders the duration of life does not exceed the brief space of twelve months, whereas it may be safely inferred from experiment 4 that *Segestria senoculata* does not even complete its several changes of integument and arrive at maturity in less than two years. The individual there stated to have had the digital joint of the left palpus detached on the 18th of May 1839 was then about two-thirds grown, and must have been disengaged from the egg in the summer of the preceding year, as this species breeds in the months of May and June in North Wales. On the 28th of June 1840, the third summer of its existence, it underwent its last moult and became adult. Subsequent experiments made with both sexes of this spider tend to corroborate the accuracy of the above conclusion.

Variations in the colour and size of spiders of the same kind, resulting from differences in age, sex, food, climate, and other conditions of a less obvious character, as they conduce largely to the introduction of fictitious species, have long engaged the attention of arachnologists, while those arising from extraordinary organic modifications, in consequence, perhaps, of their less frequent occurrence, have been almost entirely overlooked. The importance which cases of the latter description possess in relation to physiology and systematic arrangement will be best illustrated by a few examples.

1. A supernumerary eye, situated between the two small ones constituting the anterior intermediate pair, has been observed in an adult female *Theridion filipes*. The total number of eyes possessed by this individual was nine and their arrangement symmetrical.

2. An immature female *Thomisus cristatus* had the two lateral pairs of eyes only; the four small intermediate ones were altogether wanting, not the slightest rudiment of them being perceptible even with the aid of a powerful magnifier.

3. A short but perfectly formed supernumerary tarsus, connected with the base of the tarsal joint of the right posterior leg on its outer side, has been noticed in an adult female *Lycosa campestris.*

4. Deficiency of the right intermediate eye of the anterior row has been remarked in an adult male *Lycosa cambrica.*

5. The left intermediate eye of the posterior row was perceived to be wanting in an adult female *Epëira inclinata,* and the right intermediate eye of the same row was not half the usual size.

6. An adult female *Ciniflo atrox* was found to be without the left intermediate eye of the posterior row.

7. The right intermediate eye of the posterior row in an adult female *Epëira inclinata* had not one-eighth of the natural size, being merely rudimentary.

The particulars stated in the foregoing cases, which serve to establish the fact, that spiders, in common with many other animals, occasionally exhibit instances of anomalous structure, derive no small degree of interest from their novelty; but when it is borne in mind that all the examples except one have reference to those important organs the eyes, important, not only as regards the function they perform, but also on account of the extensive use made of them in the classification of the *Araneidea,* that interest becomes greatly augmented.

As spiders with four eyes have not yet been found, it is a matter of some consequence to caution observers against mistaking a mere defect in structure, like that recorded in case 2, for such a discovery. Whether there are species provided with an odd number of eyes or not is at present conjectural; should such exist, symmetry in the arrangement of their visual organs certainly may be expected to obtain; consequently, cases 4, 5 and 6, which present instances of an odd number of eyes disposed irregularly, would be regarded at all times with suspicion; as no such objection, however, can be urged against case 1, a solution of the difficulty it presents must be sought for in a more accurate acquaintance with the species.

Interesting chiefly in a physiological point of view, cases 3 and 7 show that a liability to irregularity in structure is not limited to the eyes, and that those organs are subject to preternatural variations in size as well as number.

The obscurity in which the cause of these remarkable organic modifications is involved, careful investigation, conducted upon sound philosophical principles, can alone dispel*.

Argyroneta aquatica, Dolomedes fimbriatus, and *Lycosa piratica* are known to descend spontaneously beneath the surface of water, the time during which they can respire when immersed depending upon the quantity of air confined by the circumambient liquid among the hairs with which they are clothed. There are, however, some spiders of small size, *Erigone atra* and *Savignia frontata,* for example, which, though they do not enter water voluntarily, can support life in it for many days, and that without the external supply of air so essential to the existence of *Argyroneta aquatica* under similar circumstances. It is probable that this property may contribute to their preservation through the winter, when their hybernacula are liable to be inundated†.

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* Annals and Magazine of Natural History, vol. xi. p. 165–168.

† Report of the Third Meeting of the British Association for the Advancement of Science, held at Cambridge in 1833, p. 446.

Spiders, though extremely voracious, are capable of enduring long abstinence from food. A young female *Theridion quadripunctatum*, captured in August 1829, was placed in a phial and fed with flies till the 15th of October, in the same year, during which period it accomplished its final moult and attained maturity. It was then removed to a smaller phial, which was closely corked and locked up in a book-case, its supply of food being at the same time discontinued. In this situation it remained till the 30th of April 1831, on which day it died, without receiving the slightest nourishment of any description. Throughout its captivity it never failed to produce a new snare when an old one was removed, which was frequently the case; and it is a fact particularly deserving of attention, that the alvine evacuations were continued, in minute quantities and at very distant intervals, to the termination of its existence*.

When about to deposit their eggs, spiders usually spin for their reception silken cocoons displaying much diversity of form, size, colour, and consistency. Those of the *Lycosæ* have a lenticular, or spherical figure and compact structure, with the exception of a narrow zone of a delicate texture by which they are encircled. In constructing their cocoons, these spiders slightly connect the margins of the two compact portions, beneath which the thin fabric of the zone is folded. This simple contrivance affords an admirable provision for the development of the young in the fœtal state by an enlarged capacity in the cocoons consequent on the margins of the compact parts becoming detached by the expansive force within, the eventual liberation of the young being effected by the rupture of the zone.

Theridion callens fabricates a very remarkable balloon-shaped cocoon about one-eighth of an inch in diameter. It is composed of soft silk of a loose texture and pale brown colour, enclosed in an irregular network of coarse, dark red-brown silk; several of the lines composing this network unite near the lower and smaller extremity of the cocoon, leaving intervals there through which the young pass when they quit it, and, being cemented together throughout the remainder of their extent, form a slender stem, varying from one-tenth to half of an inch in length, by which the cocoon is attached to the surface of stones and fragments of rock, resembling in its figure and erect position some of the minute plants belonging to the class *Cryptogamia*. The eggs are large, considering the small size of the spider, five or six in number, spherical, not agglutinated together, and of a brown colour†.

An elegant vase-shaped cocoon, composed of white silk of a fine compact texture, and attached by a short foot-stalk to rushes, the stems of grass, heath, and gorse, is constructed by *Agelena brunnea*; it measures about one-fourth of an inch in diameter, and contains from forty to fifty yellowish-white, spherical eggs enveloped in white silk connected with the interior of the cocoon contiguous to the foot-stalk. Greatly to the disadvantage of its appearance, the entire cocoon is smeared with moist soil, which drying serves to protect it from the weather, and as an additional security, the extremity is closed and directed downwards.

Theridion riparium fabricates a slender, conical tube of silk of a very slight texture, measuring from one and a half to two and a half inches in length, and about half an inch in diameter at its lower extremity. It is closed above, open below, thickly covered externally with bits of indurated earth, small stones, and withered leaves and flowers, which are incorporated with it, and is suspended perpendicularly, by lines attached to its sides and apex, in the irregular snare constructed by this species. In the upper part of this singular

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* Researches in Zoology, pp. 302, 303.

† Transactions of the Linnæan Society, vol. xviii. p. 629.

domicile the female spins several globular cocoons of yellowish-white silk of a slight texture, whose mean diameter is about one-eighth of an inch, in each of which she deposits from twenty to sixty small spherical eggs of a pale yellowish-white colour, not agglutinated together. The young remain with the mother for a long period after quitting the cocoons, and are provided by her with food, which consists chiefly of ants*.

Oonops pulcher constructs several contiguous, subglobose cocoons of white silk of a fine but compact texture in the crevices of rocks and walls, and among lichens growing on the trunks of trees; each measures about one-sixteenth of an inch in diameter and usually comprises two spherical, pink eggs, not agglutinated together. It may be remarked, by way of contrast, that *Epëira quadrata* frequently deposits between nine hundred and a thousand spherical eggs of a yellow colour, in a globular cocoon of coarse yellow silk of a loose texture, measuring seven-tenths of an inch in diameter, which is attached to the stems of heath, gorse, and other vegetable productions in the vicinity of its haunts.

Among the silken snares fabricated by spiders for the purpose of capturing their prey, the most elegant are those constructed with the appearance of geometrical precision in the form of circular nets. They are composed of an elastic spiral line thickly studded with minute globules of liquid gum, whose circumvolutions, falling within the same plane, are crossed by radii converging towards a common centre, which is immediately surrounded by several circumvolutions of a short spiral line devoid of viscid globules, forming a station from which the toils may be superintended by their owner without the inconvenience of being entangled in them. As the radii are unadhesive and possess only a moderate share of elasticity, they must consist of a different material from that of the viscid spiral line, which is elastic in an extraordinary degree. Now the viscidity of this line may be shown to depend entirely upon the globules with which it is studded, for if they be removed by careful applications of the finger, a fine glossy filament remains, which is highly elastic, but perfectly unadhesive. As the globules, therefore, and the line on which they are disposed, differ so essentially from each other, and from the radii, it is reasonable to infer that the physical constitution of these several portions of the net must be dissimilar.

An estimate of the number of viscid globules distributed on the elastic spiral line in a net of *Epëira apoclisa* of a medium size, will convey some idea of the elaborate operations performed by the *Epëiræ* in the construction of their snares. The mean distance between two adjacent radii, in a net of this species, is about seven-tenths of an inch; if, therefore, the number 7 be multiplied by 20, the mean number of viscid globules which occur on one-tenth of an inch of the elastic spiral line, at the ordinary degree of tension, the product will be 140, the mean number of globules deposited on seven-tenths of an inch of the elastic spiral line; this product multiplied by 24, the mean number of circumvolutions described by the elastic spiral line, gives 3360, the mean number of globules contained between two radii; which multiplied by 26, the mean number of radii, produces 87,360, the total number of viscid globules in a finished net of average dimensions. A large net, fourteen or sixteen inches in diameter, will be found, by a similar calculation, to contain upwards of 120,000 viscid globules, and yet *Epëira apoclisa* will complete its snare in about forty minutes if it meet with no interruption.

In the formation of their snares the *Epëiræ* appear to be regulated solely by the sense of touch, as various species when confined in spacious glass jars

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* Researches in Zoology, p. 356.

placed in situations absolutely impervious to light construct nets which do not exhibit the slightest irregularity of plan or defect of structure*.

Dr. Lister supposed that spiders are able to retract the lines they spin within the abdomen, and whoever minutely observes the *Epëiræ,* when fabricating their snares, will almost be induced to entertain the same opinion. The viscid line produced by these spiders in their transit from one radius to another is sometimes drawn out to a much greater extent than is necessary to connect the two, yet, on approaching the point at which it is to be attached, it appears to re-enter the spinners, till it is reduced to the exact length required. This optical illusion, for such it is, is occasioned by the extreme elasticity of the line, which may be extended greatly by the application of a slight force, and on its removal will contract proportionally. By this property the viscid spiral line is accommodated to the frequent and rapid changes in distance which take place among the radii when agitated by winds or other disturbing forces, and by it insects, which fly against the snare, are more completely entangled than they otherwise could be without doing extensive injury to its frame-work†.

Complicated as the processes are by which these symmetrical nets are produced, nevertheless, young spiders, acting under the influence of instinctive impulse, display, even in their first attempt to fabricate them, as consummate skill as the most experienced individuals.

Although spiders are not provided with wings, and, consequently, are incapable of flying, in the strict sense of the word; yet, by the aid of their silken filaments, numerous species, belonging to various genera, are enabled to accomplish distant journeys through the atmosphere. These aërial excursions, which appear to result from an instinctive desire to migrate, are undertaken when the weather is bright and serene, particularly in the autumn, both by adult and immature individuals, and are effected in the following manner. After climbing to the summits of different objects, they raise themselves still higher by straightening the limbs; then elevating the abdomen, by bringing it from the usual horizontal position into one almost perpendicular, they emit from the spinners a small quantity of viscid fluid, which is drawn out into fine lines by the ascending current occasioned by the rarefaction of the air contiguous to the heated ground. Against these lines the current of rarefied air impinges, till the animals, feeling themselves acted upon with sufficient force, quit their hold of the objects on which they stand and mount aloft.

Spiders do not always ascend into the atmosphere by a vertical movement, but are observed to sail through it in various directions; and the fact admits of an easy explanation when the disturbing causes by which that subtile medium is liable to be affected are taken into consideration. A direction parallel to the horizon will be given by a current of air moving in that plane; a perpendicular one, by the ascent of air highly rarefied; and directions intermediate between these two will, in general, depend upon the composition of forces. When the horizontal and vertical currents are equal in force, the line of direction will describe an angle of 45° nearly with the plane of the horizon; but when their forces are unequal, the angle formed with that plane will be greater or less as one current or the other predominates.

The manner in which the lines of spiders are carried out from the spinners by a current of air appears to be this. As a preparatory measure, the spinning mammulæ are brought into close contact, and viscid matter is emitted

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* Zoological Journal, vol. v. p. 181–188. Transactions of the Linnæan Society, vol. xvi. p. 477–479. Researches in Zoology, p. 253–270.

† Researches in Zoology, pp. 267, 268.

from the papillæ; they are then separated by a lateral motion, which extends the viscid matter into fine filaments connecting the papillæ; on these filaments the current impinges, drawing them out to a length which is regulated by the will of the animal; and on the mammulæ being again brought together the filaments coalesce and form a compound line.

Many intelligent naturalists entertain the opinion that spiders can forcibly propel or dart out lines from their spinners; but when placed on twigs set upright in glass vessels with perpendicular sides containing a quantity of water sufficient to immerse their bases completely, all the efforts they make to effect an escape uniformly prove unavailing in a still atmosphere. However, should the individuals thus insulated be exposed to a current of air either naturally or artificially produced, they immediately turn the abdomen in the direction of the breeze, and emit from the spinners a little of their viscid secretion, which being carried out in a line by the current becomes connected with some object in the vicinity, and affords them the means of regaining their liberty. If due precaution be used in conducting this experiment, it clearly demonstrates that spiders are utterly incapable of darting lines from their spinners, as they cannot possibly escape from their confinement on the twigs in situations where the air is undisturbed, but in the agitated atmosphere of an inhabited room they accomplish their object without difficulty. Similar means are frequently employed by spiders in their natural haunts for the purposes of changing their situation and fixing the foundations of their snares.

The webs named gossamer are composed of lines spun by spiders, which on being brought into contact by the mechanical action of gentle airs adhere together, till by continual additions they are accumulated into irregular white flakes and masses of considerable magnitude. Occasionally spiders may be found on gossamer-webs after an ascending current of rarefied air has separated them from the objects to which they were attached, and has raised them into the atmosphere; but as they never make use of them intentionally in the performance of their aëronautic expeditions, it must always be regarded as a fortuitous circumstance*.

On the Construction of Large Reflecting Telescopes.

By the EARL OF ROSSE.

THE Council having intimated their opinion that some account of the experiments in which I have been engaged on the reflecting telescope would not be altogether devoid of interest, I will endeavour to describe as briefly as possible the manner in which I have attempted to accomplish the object in view, and the principal results obtained.

Having concluded that upon the whole there was a better prospect of obtaining by reflexion rather than by refraction the power which would be required for making any effectual progress in the re-examination of the nebulæ, the first experiments were undertaken in the hope of obviating the difficulties which had previously prevented the application of the brilliant alloy, which may be formed of tin and copper in proper proportions, to the construction of large instruments. The manner in which the difficulty had been met was by adding an excessive proportion of copper to the alloy, but the mirror was no longer susceptible of a durable polish, and when used its powers declined rapidly.

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* Transactions of the Linnæan Society, vol. xv. p. 449–459. Researches in Zoology, p. 229–252.

It appeared to me, therefore, to be an object so important to obtain a reflecting surface which would reflect the greatest quantity of light, and retain that property little diminished for a length of time, that numerous experiments were undertaken and perseveringly carried on. After a number of failures, the difficulties appeared to be so great that I constructed three specula, where the basis of the mirror was an alloy of zinc and copper in the proportion of 1 zinc to 2·74 copper, which expands with changes of temperature in the same proportion as speculum metal. This was subsequently plated with speculum metal, in pieces of such size as we were enabled to cast sound. These specula were very light and stiff, and their performance upon the whole satisfactory; but they were affected by diffraction at the joinings of the plates, and although very brilliant and durable, defining all objects well under high powers, except very large stars, still as the effect of diffraction was then perceptible, they could not be considered as perfect instruments. In the course of the experiments carried on while these three specula were in progress, it was ascertained that the difficulty of casting large discs of brilliant speculum metal arose from the unequal contraction of the material, which in the first instance produced imperfections in the castings and often subsequently their total destruction; and it appeared evident that if the fluid mass could be cooled throughout with perfect regularity, so that at every instant every portion should be of the same temperature, there would be no unequal contraction in the progress towards solidification, nor subsequently in the transition from a red heat to the temperature of the atmosphere. Although it was obvious that the process could not be managed so that the exact condition required should be fulfilled, still by abstracting heat uniformly from one surface (the lower one), the temperature of the mass would be kept uniform in one direction, that is, horizontally; while in the vertical direction it would vary in some degree as the distance from the cooling surface. These conditions being satisfied, we should likewise have a mass which would be free from flaws, and when cool would be free from sensible strain: nothing could be easier than to accomplish this approximately in practice; it would be only necessary to make one surface of the mould (the lower one) of iron, of a good conducting material, while the remainder was of dry sand. On trial this plan was perfectly successful; there was however a new, though not a very serious defect, which was immediately apparent; the speculum metal was cooled so rapidly, that air-bubbles remained entangled between it and the iron surface, but the remedy immediately suggested itself; by making the iron surface porous, so as to suffer the air to escape, in fact by forming it of plates of iron placed vertically side by side, the defect was altogether removed. It only then remained to secure the speculum from cooling unequally, and for that purpose it was sufficient to place it in an oven raised to a very low red heat, and there to leave it till cold, from one to three or four weeks, or perhaps longer, according to its size.

The alloy which I consider the best differs but little from that employed by Mr. Edwards; I omit the brass and arsenic, employing merely tin and copper in the atomic proportions, namely, one atom of tin to four atoms of copper, or by weight, 58·9 to 126·4. As it was obviously impossible to cast large specula in earthen crucibles, the reverberatory furnace was tried, but the tin oxidized so rapidly that the proportions in the alloy were uncertain, and after some abortive trials with cast iron crucibles, it was found that when the crucible is cast with the mouth up, it is free from the minute pores through which the speculum metal would otherwise exude; and therefore such crucibles fully answered the purpose.

It was very obvious that the published processes for grinding and polishing specula, being in a great measure dependent on manual dexterity, were uncertain and not well-suited to large specula; accordingly, at an early period of these experiments, in 1827, a machine was contrived for the purpose which has subsequently been improved, and by means of it a close approximation to the parabolic figure can be obtained with certainty: as it has been described in the Philosophical Transactions for 1840, it is unnecessary to do more than to point out the principle on which it acts; the speculum is made to revolve very slowly, while the polishing tool is drawn backwards and forwards by one excentric or crank, and from side to side slowly by another. The polishing tool is connected with the excentrics by a ring which fits it loosely, so as to permit it to revolve, deriving its rotatory motion from the speculum, but revolving much more slowly. It is counterpoised so that it may be made sufficiently stiff, and yet press lightly on the speculum, the pressure being about one pound for every circular superficial foot. The motions of this machine are relatively so adjusted, that the focal length of the speculum during the polishing process, or towards the latter end of it, shall be gradually becoming slightly longer; and the figure will depend in a great measure upon the rapidity with which this increase in the focal length takes place. It will be evident that a surface spherical originally will cease to be so if, while subjected to the action of the polisher, it is in a continual state of transition from a shorter to a longer focus; in fact during no instant of time will it be actually spherical, but some curve differing a little from the sphere, and which may be made to approach the parabola, provided it be possible in practice to give effect to certain conditions.

An immense number of experiments, where the results were carefully registered, eventually established an empirical formula, which affords at present very good practical results, and may hereafter perhaps be considerably improved. In fact, when the stroke of the first excentric is one third the diameter of the speculum, and that of the second excentric is such as to produce a lateral motion of the bar which moves the polisher, measured on the edge of the tank, equal to 0·27, the diameter of the speculum, (or referred to the centre of the polisher to 0·17,) the figure will be nearly parabolic. The velocity and direction of the motions which produce the necessary friction being adjusted in due proportion by the arrangements of the machine, and the temperature of the speculum being kept uniform by the water in which it is immersed, there remain still other conditions which are essential to the production of the required result. The process of polishing differs very essentially from that of grinding; in the latter, the powder employed runs loose between two hard surfaces, and may produce scratches possibly equal in depth to the size of the particles; in the polishing process the case is very different; there the particles of the powder lodge in the comparatively soft material of which the surface of the polishing tool is formed, and as the portions projecting may bear a very small proportion to the size of the particles themselves, the scratches necessarily will be diminished in the same proportion. The particles are forced thus to imbed themselves, in consequence of the extreme accuracy of contact between the surface of the polisher and the speculum. But as soon as this accurate contact ceases, the polishing process becomes but fine grinding. It is absolutely necessary therefore to secure this accuracy of contact during the whole process; if the surface of a polisher of considerable dimensions is covered with a thin coat of pitch of sufficient hardness to polish a true surface, however accurately it may fit the speculum, it will very soon cease to do so, and the operation will fail. The reason is this, that particles of the polishing powder and abraded matter will collect in one place more than another, and as the pitch is not elastic, close contact throughout the surfaces will cease. By employing a coat of pitch, thicker in proportion as the diameter of the speculum is greater, there will be room for lateral expansion, and the prominence can therefore subside and accurate contact still continue; however, accuracy of figure is thus to a considerable extent sacrificed. By thoroughly grooving a surface of pitch, provision may be made for lateral expansion contiguous to the spot where the undue collection of polishing powder may have taken place. But in practice such grooves are inconvenient, being constantly liable to fill up; this evil is entirely obviated by grooving the polisher itself, and the smaller the portions of continuous surface, the thinner may be the stratum of pitch.

There is another condition which is also important, that the pitchy surface should be so hard as not to yield and abrade the softer portions of the metal faster than the harder; when the pitchy surface is unduly soft, this defect is carried so far that even the structure of the metal is made apparent. While therefore it is essential that the surface in contact with the speculum should be as hard as possible consistent with its retaining the polishing powder, it is necessary that there should be a yielding where necessary, or contact would not be preserved; both conditions can be satisfied by forming the surface of two layers of resinous matter of different degrees of hardness; the first may be of common pitch adjusted to the proper consistence, by the addition of spirits of turpentine or rosin, and the other I prefer making of rosin, spirits of turpentine and wheat flour, as hard as possible consistent with its holding the polishing powder. The thickness of each layer need not be more than $\frac{1}{40}$th of an inch, provided no portion of continuous surface exceeds half an inch in diameter; the hard resinous compound, after it has been thoroughly fused, can be reduced to powder, and thus easily applied to the polisher, and incorporated with the subjacent layer by instantaneous exposure to flame. A speculum of three-feet diameter thus polished has resolved several of the nebulæ, and in a considerable proportion of the others has shown new stars, or some other new feature; and by the same processes a speculum of six feet diameter has just been completed.

Report on a Gas Furnace for Experiments on Vitrifaction and other Applications of High Heat in the Laboratory.

By the Rev. WILLIAM VERNON HARCOURT, *F.R.S., &c.*

HAVING commenced in 1834 some experiments on vitrifaction, the object of which was to determine the conditions of transparency in glass, and to compare the chemical constitution with the optical properties of different glasses, I was encouraged by a recommendation which is printed in the 4th volume of the Transactions of the British Association to pursue the subject further.

I am not, however, prepared at present to report the progress which I have made in these researches, except so far as to give an account to the meeting of the manner in which I have endeavoured to surmount the first great difficulty attendant on such inquiries.

In Dr. Faraday's account of the experiments made in the laboratory of the Royal Institution for the improvement of glass for optical purposes (Phil. Trans., 1830, part 1.), he has noticed the obstacles which he encountered from the reducing property of the gases produced by carbonaceous fuel, and the contrivance by which he overcame the difficulty for the particular object which he had in view; this, however, and other inconveniences from the smoke, the dust, and the cumbrousness of an ordinary furnace, together with the impossibility of regulating the application of the heat and of watching the progress of the experiment, have combined to hinder chemists from multiplying observations on fusion, or examining with accuracy the phænomena of vitrifaction.

On considering what might be the best means of obtaining a great range of heat for such purposes not subject to the disadvantages above mentioned, and of ready application and œconomical use, it occurred to me that hydrogen gas, self-condensed in a vessel sufficiently strong, and allowed to issue with greater or less rapidity through very fine apertures, would furnish a fuel and furnace to answer these requirements.

In 1836 I expended the sum granted by the Association in executing the apparatus which I had thus conceived; and the instrument which I have now the honour of exhibiting to the Section, and of which I propose to show the working, is constructed on the same principles, but somewhat reduced in size and altered in arrangement, so as to render it more compact and portable.

These instruments were made at Bermondsey at the engine-factory of Messrs. Bryan Donkin, to whom I am indebted for many valuable suggestions, and whose name is a sufficient warrant for the excellence of the workmanship, and for the care with which the strength of every part of the apparatus has been ascertained. Strength is indispensable, since the principle on which in this instrument I depend for obtaining perfect combustion and a rapid accumulation of heat is the velocity of the jets, issuing under a high degree of compression. When I stated to the late Dr. Dalton, in 1835, the pressure at which I proposed to work, he expressed a doubt whether the cold which would be produced by the great expansion of the gas might not be found materially to detract from the heat; and it does happen, either from this cause, or as Dr. Faraday suggests, from the effect of successive explosions, that if a strong pressure is put on at first, the jets refuse to inflame, or blow themselves out; but when the object on which they are directed is once heated to a certain point, the intensity of the heat rises in proportion to the velocity of the jets. The first instrument was tested by the hydraulic press to a pressure of 160 atmospheres, and I have worked it when showing 80 in the gauge: that which is now before the Section has been tested to 60 atmospheres, and in the experiments which I shall show will not be subject to more than from 25 to 30. I need scarcely add that under such circumstances, the maximum condensation of the gas being determined by the quantity of materials used for its production, and the gas itself being hydrogen almost unmixed and consequently wholly inexplosive, these experiments are free from all suspicion of danger. The tightness of every part of the apparatus may be safely tried by a lighted taper, and if through any accidental leakage the gas takes fire, it is easily extinguished by shutting the stop-cock or screwing up the loose joint.

The vessel in which the gas is generated and accumulated is a tube (see Plate XXIV.) of drawn iron, closed at the lower end by welding and lined with an internal tube of lead, of convenient height for manipulation, and hung by the middle on a swivel, so as to be readily reversed and emptied of its contents. On the upper end of the tube-turned conical a flanged iron cap is driven and screwed, and on the cap a strong brass plate is screwed and rendered air-tight by a leaden washer between it and the iron cap, which leaden washer is soldered to the top of the internal tube of lead, and thus prevents the acid penetrating between the iron tube and lead lining. In the brass plate is a central aperture, in the form of a deep hollow cone, inverted and truncated, which receives a hollow conical stopper, also of brass, ground to fit it, and furnished with a stop-cock and tubular head, connected by means of an union-joint with the rest of the apparatus. Two wedge-shaped ears stand out from the stopper above the conical part, and when the joint is to be secured pass under the inclined planes of two corresponding wedges screwed to the brass plate. By this contrivance, due to the ingenuity of Mr. Bryan Donkin, jun., a quarter of a turn of the stopper suffices to secure the joint, which is afterwards at leisure more tightly fastened down by two additional screws.

The aperture in the brass plate gives admission to a colander of the same length as the tube, made of copper, and designed to hold the charge of zinc.

A conducting pipe of copper tubing connects, by means of union-joints, the tubulated *stopper* with a *brass stand*, in which is a *chamber* where the gas is cleansed after having been partially dried by sponge introduced into the cavities of the stopper. In this chamber a glass vessel is placed which contains absorbent materials, and to the bottom of which the gas is conveyed by a tube.

With the chamber are connected by similar copper tubing two supports for burners, the supply of gas to which is commanded by two stop-cocks attached to the chamber, so that they may be employed either separately or together.

I have contrived various forms of burners for different purposes: that which is best adapted for concentrating heat is a truncated brass cone ground within another cone, and inscribed on its face with lines converging to the axis. But for the purpose of bringing a vessel to an uniform temperature, the jets of flame must be directed in the manner best fitted to distribute the heat: a fine jet of hydrogen issuing with such force as to create a strong current of air, and thus blow, as it were, its own bellows, produces very intense heat, a heat so intense that I have fused with it at high pressures hyacinths and jargoons: even at the lower pressure, which I am now going to use, vessels of platina are liable to be melted at the extremities of the jets, whilst at the intervals between them the metal is far below the point of fusion. I determined, therefore, to attempt to equalise the temperature by giving the vessels a rotatory motion, so that the jets of flame might act on successive points at successive moments; and I arranged the jets in spirals, flat or elevated, as dishes and crucibles of different forms required, so that each jet should describe a separate circle on the surface revolving before its point, and that those circles should be equally distributed over the surface of the vessel: the burners are copper tubes twisted into the required forms, and furnished with nipples tipped with platina, finely bored, and screwed into the tube. By this arrangement the currents of air pass uninterrupted, the tubes are not in danger of being fused, and the number of jets may be regulated by plugging more or fewer of the apertures within the screws. To effect the rotation, I adapted a watch-movement to the wires from which the crucibles depend; and, at Mr. Donkin's suggestion, I use for the same purpose a light fan, which is moved by the heat of the burner: for low heats this does not answer so well as the watch-movement, but at high temperatures it has the advantage of increasing the velocity of the rotation in proportion to the intensity of the heat.

Another copper pipe, connecting by union-joints the chamber with a *gauge*, completes the apparatus. The gauge consists of a double iron chamber containing mercury; into the upper part of the inner chamber a strong glass tube is secured by leaden washers and a perforated screw: the graduations of the tube begin with eight atmospheres and are carried to 150.

On the present occasion I intend to employ a quantity of gas, which, if liberated at once, would give a pressure of about 66 atmospheres, but at the rate at which it is actually formed will in ten minutes give about one-third of that pressure. For this purpose I have poured into the generating tube 10½ pints of water and ¾ of a pint of oil of vitriol, and have allowed the mixture to cool. I now introduce the colander, into which I have put 15 ounces of strips of rolled zinc, and close the stop-cock. The capacity of the apparatus is such, that after being thus charged, the whole space left for the gas to accumulate in is nearly equal to four pints, and the volume of hydrogen extricated in ten minutes is in round numbers 3000 cubic inches at the pressure of one atmosphere, which give in this case a pressure of 22 atmospheres in the gauge.

The Section will now see, that by a greater or less opening of the stop-cocks a very extensive range of heat is commanded, according to the quantity of gas which I allow to pass, so that the platina vessels may be brought gradually or instantly from a moderate temperature to the highest white heat which they are capable of bearing; and it will be observed that the whole surface of the crucible is heated with great uniformity when revolving within the helical burner. This very intense heat might be continued, with the present charge and burner of six jets, for nearly twenty minutes, and may be discontinued and resumed at pleasure; for such is the accuracy of the fitting, that no material loss of gas occurs in many hours when the stop-cocks are closed.

Higher charges may be safely employed than I have here used, and the accumulation of the gas may be retarded or accelerated by varying the strength and volume of the charge; but this will suffice to show the use and power of the instrument. The invention of new instruments is often the first step to the discovery of new facts and laws, and therefore I have bestowed both a good deal of attention, and also of expense beyond the liberal grant made by the Association, on this instrument, in the hope of bringing within the reach of chemists as full a command of high heats as of low, with such œconomy of time, trouble and cost as may make it practically available.

The actual cost of the apparatus here exhibited is enhanced by some supplementary parts, serviceable in the first construction and regulation of it, but not essential probably to its practical use; and if the gauge and separate drying-chamber, which are of this character, be deducted, the instrument may be constructed at a moderate price.

The expense of the charge which I have now used is less than sixpence; the trouble of charging and re-charging is less than that of lighting and re-lighting a fire. The only part of these operations which requires time is the cooling the mixture of the acid and water, a precaution advisable when a strong charge is used, lest the heat thus generated, added to that produced by the solution of the zinc, should occasion an inconvenient evolution of steam.

With the aid of this instrument I have made various experiments on vitrifaction, especially on that of phosphoric glasses, into the detail of which, as they are still in progress, I will not at present enter. The Section will, however, see on the table various specimens of vitrified compounds, which tend to illustrate some leading principles in the manufacture of glass, and with regard to which I shall be happy to furnish the Section with any information that may be desired.

Report of the Committee for registering Earthquake Shocks in Scotland.

THE place where, as usual, these shocks have been most felt during the last twelve months, is Comrie in Perthshire; thirty-seven shocks have been felt there during that time; but few were so violent as to produce any effects beyond the neighbourhood of that town.

The following is a list of the shocks registered at Comrie by Mr. Macfarlane, post-master there, who takes charge of the instruments belonging to the Association:—

REGISTER FOR

EXPLA-

A The hours of the day before noon to be indicated by A, the hours after noon to be
4 o'clock in the

B Marking the least perceptible as 1, and a shock equal to that on Oct. 23, 1839, as 10,
loud as shock re-

C If the concussion be single, to be marked C; if double, CC; but if the second be smaller
would indicate two shocks, the

D To be entered C, H, or T, according as it has been a Crash, Heave, or Tremor, or two,
would indicate a shock beginning with a slight concussion, then a considerable heave,
the three qualities

E The first column here is merely for entering the direction the shock *appeared* to the
the Dip to be entered of course only where the

F In like manner, in these columns the height of Barometer and Thermometer to be en-
wind to be indicated by 1 for the gentlest current,

G Where there is no rain-gauge the quantity of rain to be marked in general by the letters

	A			B				C	D	E				F				
Year 1843-4.	Time of the day.			Violence of the		Duration in Seconds.		Concussion, single or double.	Crash, Heave, Tremor.	Direction.				Instant of Shock.				
											Marked by the Seismometer.					Wind.		
Day of the Month.	Hour.	Minute.	A or P.	Shake.	Sound.	Shake.	Sound.			As felt.	Point of Compass.	Extent of Vibration.	Dip in parts of an inch.	Barometer.	Thermometer.	Direction.	Strength.	Sky dark or clear.
Aug. 25.	10	40	A	5	5	3	4	C c	Cht.	...	W	$\frac{3}{4}$	$\frac{1}{4}$	29·5	56	S	2	D
—— 25.	11	...	A	1	1	1	1	c	c	...	...	...	...	...	...	...	...	...
—— 25.	5	...	P	1	1	1	1											
Sept. 1.	5	15	A	2	2	2	2	c	t	...	...	...	...	...	...	...	...	...
—— 2.	12	...	A	2	3	2	2	c	t	...	...	...	...	...	...	...	...	...
—— 2.	6	...	A	1	1	1	1	...	...	...	...	...	...	30·15	60	...	...	...
—— 16.	11	...	A	1	1	1	1	...	...	...	...	..	...	...	...	...	...	...
Nov. 25.	2	...	A	1	1	1	1	...	...	...	...	..	...	...	...	...	...	...
—— 26.	4	...	A	2	2	2	2	c	t	...	...	...	...	...	...	...	...	...
—— 30.	...	...	A	1	1	1	1	...	t	...	...	...	...	...	...	...	...	...
—— 30.	...	...	A	1	1	1	1	...	t	...	...	...	...	...	...	...	...	...
Jan. 1.	2	...	A	1	1	1	1	c	t	...	...	...	...	...	...	...	...	...
—— 3.	3	...	A	1	1	1	1	c	t	...	...	...	...	...	...	...	...	...
—— 9.	5	...	A	1	1	1	1	c	t	...	...	...	...	...	...	...	...	...
—— 14.	1	...	P	3	4	2	3	...	T									
—— 14.	1	10	P	1	1	1	1	c	t									
—— 14.	1	20	P	1	1	1	1	c	t									
—— 14.	1	37	P	2½	4	2	3	...	T									
—— 14.	2	...	P	1	1	1	1	c	t		0	0	$\frac{3}{8}$	...	...	...	...	...
—— 14.	9	...	P	1	1	1	1	...	t									
—— 14.	11	...	P	1	1	1	1	...	t									
—— 14.	11	45	P	1	1	1	1	...	t									
—— 23.	2	...	A	1	1	1	1	...	t	...	...	...	...	...	...	...	...	...
Feb. 6.	4	...	A	1	1	1	1	...	t	...	...	...	...	...	...	...	...	...
—— 16.	...	...	A	1	1	1	1	...	t	...	...	...	...	...	...	...	...	...
—— 20.	6	30	A	1	1	1	1	...	t	...	...	...	...	...	...	...	...	...
Mar. 3.	7	...	A	1	1	1	1	...	t	...	...	...	...	...	...	...	...	...
—— 19.	1	...	P	1	1	1	1	...	t	...	...	...	...	...	...	...	...	...
Apr. 1.	10	15	A	1	1	1	1	...	t	...	...	...	...	...	...	...	...	...
May 11.	10	...	P	1	1	1	1	...	t	...	...	...	...	...	...	...	...	...
—— 14.	4	...	A	1	1	1	1	...	t	...	...	...	...	...	...	...	...	...
—— 22.	7	...	A	2	2	1	2	...	t	...	...	...	...	...	...	...	...	...
—— 25.	5	30	A	1	1	1	1	...	t	...	...	...	...	...	...	...	...	...
July 9.	3	...	A	1	1	1	1	...	t	...	...	...	...	...	...	...	...	...
Aug. 25.	3	...	A	1	1	1	1	...	t	...	...	...	...	...	...	...	...	...
Sept. 1.	11	15	P	2	1	1	1	...	...	...	...	...	...	...	...	...	...	...
—— 4.	6	15	P	1	1	1	1	...	t	...	...	...	...	...	...	...	...	...

EARTHQUAKE SHOCKS.

NATIONS.

indicated by P; thus, 4 o'clock in the morning would be marked in the Table 4 A; afternoon, 4 P.
and intermediate degrees of intensity by intermediate numbers; thus, one half as violent or ferred to, to be entered 5.
than first (which is almost always the case) the latter to be marked with a small c; thus C c second weaker than the first.
or all; using the small letters here too to mark the relative force of each; thus c H t and ending in a slight tremor; and C H T, one such as that of Oct. 23, 1839, where all were intense.
observer to proceed from, most needed in slight shocks that do not affect the instruments; instrument enables the observer to ascertain it.
tered only by those observers who have such instruments at hand. The strength of the and 10 for a hurricane; and a calm, 0.
M, much, and L, little.

F					G	
Five minutes after Shock.					Rain for eight days previous.	Other particulars not included in preceding list, that might be considered as either directly or indirectly connected with the shocks.
Barometer.	Thermometer.	Wind.		Sky dark or clear.		
		Direction.	Strength.			
29·6	55	SW	1	D	L	The direction and dip in this case (10. 40. A) given most distinctly by spiral pendulum in steeple. The horizontal force one in Post-office attics ranged fully half an inch. Day cloudy, cold and showery. Close rain from 2 to 4½ P.; mostly fair afterwards. Next day (26) cloudy with occasional sunshine; much thunder at 2 P., and cloudy with light rain afterwards.
...	...	...	...	...	...	
...	...	...	...	...	...	Other three slight shocks observed by some during the night between the 1st and 2nd; rain in morning of 2nd; light, cloudy, mild, moist and warm day.
...	...	...	...	...	L	
30·15	60	...	...	...	...	Fine harvest morning; splendid dry fine night.
...	...	...	...	...	...	Morning cloudy; day also; with occasional blinks of sunshine.
...	...	...	...	...	...	Day dark; drizzling rain occasionally. This shock observed only at Tomperran.
...	...	...	...	...	...	Most dark and dull; rain at night.
...	...	...	...	...	...	Very dark morning; much rain through the day.
...	...	...	...	...	...	Very dark morning; much rain through the day.
...	...	...	...	...	...	Frosty, clear and sunshine.
...	...	...	...	...	...	Dim and cloudy; a fall of about 1 in. snow during the night; a.m. sunshine; p.m. overcast.
...	...	...	...	...	...	Very dark and overcast; after 10½ sleet and snow.
...	...	...	...	...		In all 8 shocks to-day. During first 5 days bright and sunny. Barometer at 3 o'clock at 30·2; ext. thermometer 35. Wind gentle and S. W. all day. Spiral in steeple indicated 3-8ths in perpendicular heaves; no lateral mark. Horizontal pendulum in Post-office attics indicated same amount of heaves as spiral in steeple; sand in glass had fallen 2 in. since last noticed; but part of this fall might have been owing to other causes, as it had not been marked for a month before.
...	...	...	...	...	...	Fine morning; fine day and night.
...	...	...	...	...	...	Severe frost; fine clear and dry day; night overcast.
...	...	...	...	...	...	Dull morning; showery day; clear night.
...	...	...	...	...	...	Clear sharp frost.
...	...	...	...	...	...	Dull and snowy morning; fine clear night.
...	...	...	...	...	...	Fine morning; afternoon dull, inclined to rain.
...	...	...	...	...	...	Dull foggy morning; fine day and night.
...	...	...	...	...	...	Beautiful morning; showery afternoon.
...	...	...	...	...	...	Clear, fine day; a little rain at night.
...	...	...	...	...	...	Clear morning; fine day; rain at night.
...	...	...	...	...	...	Dull morning; showery during day.
...	...	...	...	...	...	Cloudy morning; cloudy and sun-shining day.
...	...	...	...	...	...	Fine day; a little cold towards evening. This shock observed only at Tomperran.
...	...	...	...	...	...	Fine day.
...	...	...	...	...	...	Fine day. This shock observed only at Lawers.

Mr. Macfarlane observes, regarding the shock of 25th August 1843, in a letter accompanying his Register, that he had "an excellent opportunity of witnessing the effects of it on many persons, being at the time in the front of the gallery of our church, in the midst of a congregation engaged in public worship. Some became pale, others flushed; some started, others trembled; and the momentary perfect silence that followed the awful concussion and sound was really sublime. After witnessing this, I am more inclined than ever to ascribe all the various sensations experienced by many on these occasions to the effects of the sudden alarm rather than to those often alleged as the cause, such as electricity, &c. On this occasion somehow I instinctively, as it were, thought the concussion and peculiar sound arose to us from an immense depth within the earth; and that it actually did so was afterwards confirmed by the fact, that this shock was felt simultaneously over an area of more than 100 square miles, and that with nearly equal intensity throughout."

Mr. Macfarlane reports further in regard to this shock, that it moved the instruments at the following places, and produced on them the effects now to be stated:—

Kingarth, two miles north of Comrie, inverted pendulum, had point thrown to three-quarters of an inch to north-west.
Clathick, three miles east of Comrie, spiral pendulum and sand-glass; sand fell two inches.
Crieff, six miles east of Comrie, inverted pendulum, had point thrown three-quarters of an inch to west.
Invergeldie, six miles north of Comrie, inverted pendulum, had point thrown three-quarters of an inch to south-west.

In regard to the shock of 14th January 1844, Sir David Dundas of Duneira, whose house is situated about two miles W.N.W. of Comrie, writes,—"*That* shock was attended with a louder noise and a longer-continued dying-away *rumble* than many of them, and the quake was not so severe as I have experienced, though quite enough to be very disagreeable and make one feel uncomfortable. Since then there has been nothing of any consequence, and I wish I could persuade myself that we shall never have any more." Sir David adds, that "the instrument in his house, a spiral pendulum, was not affected by this or any other shock during the year. It had not been erected at the date of the shock in August 1843."

Mr. Stewart of Ardvoirlich happened at the time of this same shock to be at Balquhidder, which is about seventeen miles west of Comrie, and he writes that there were "two pretty severe shocks at an interval of from half an hour to three-quarters of an hour, accompanied by considerable rolling noise. I was at the time in Balquhidder Church, and heard and felt them distinctly. On my return home I examined the seismometer, but no perceptible motion seemed to have taken place in any direction, nor was the column of sand in the tube in any degree displaced. No earthquakes have been felt here since, so far as I have heard."

This shock of 14th January was distinctly perceived at Tyndrum, which is about thirty miles W.N.W. of Comrie. On that day, at one o'clock, an extraordinary subterranean noise was felt by the inhabitants of the village, and which was generally recognized by them to be that caused by an earthquake. The innkeeper happened to be in bed unwell, and felt it shake as well as heard the rumbling sound.

It will be observed, from the effects produced on the instruments by the shock of 25th August 1843,—1, that it was only in the village of Comrie that the ground had an upward movement, the movement in more distant places being horizontal; 2, that at all the places above-mentioned the movement came from the westward, these being all more or less to the east of the hill from which, according to former observations, the shocks emanate.

Had the instruments now at Duneira and Ardvoirlich been at that date erected, any effects on *them*, it might be expected, would have been in an opposite direction.

The meteorological observations have been faithfully carried on at Comrie under the superintendence of Mr. Macfarlane, to whose diligence and assiduity the Committee are much indebted. A complete register of these observations has been rendered to them, of which a copy is herewith sent.

When these meteorological observations have been carried on for a few years, they will afford some data for ascertaining whether, as has been generally believed, any connexion prevails between the state of the weather or time of the year with the number and violence of the shocks.

No earthquake shocks have occurred in other parts of the United Kingdom during the last year, in so far as known to the Committee, except one on the 12th of June 1844. The following notices of it have been extracted from the newspapers:—"Earthquake.—A slight shock of an earthquake was felt at *Stamford* on Wednesday evening, 12th June 1844, about seven. Many persons were sensible of the tremulous motion of the earth for ten or fifteen seconds. It was accompanied with a noise like distant thunder, and was by some mistaken for that phænomenon; but there is no doubt that it was a convulsion of the earth. At Tinwell, Ketton, Tixover, Duddington, Cliffe, Apethorp, Wansford, Collyweston, Easton, &c. &c., the shock was distinctly felt. In some of the above named villages various articles were displaced; at a gentleman's house at Easton, the bell at the outer gate was rung in consequence of the vibration produced by it."—*Stamford Mercury.* "Earthquake in *Huntingdonshire.* Yaxley, June 14.—A most severe shock of earthquake was felt here on Wednesday evening last, the 12th inst., at about half-past seven o'clock, more particularly on the hill where my house is situate, appearing like a park of artillery passing under it, shaking it to the very foundation. Scarcely a shower of rain has fallen since the 26th of March."

The Committee, in accordance with the suggestion in their last year's Report, and which they understood met with general approval, have placed a seismometer at Tyndrum, and Lord Breadalbane has given directions to his overseer there that it should be attended to. By means of instruments thus placed on all sides of the earthquaking district, and at different distances from it, additional data for inference will be obtained.

Stirling, 23rd Sept. 1844.

My dear Sir,—Since sending off the Earthquake Report I have obtained some additional information, which I would have introduced into it had I known of it before. I therefore sit down to communicate it by letter to you, in order that you may, if you see fit, take notice of it in presenting the Report.

You will see from the register, that the two most severe shocks during the last year occurred in August 1843 and January 1844. I met yesterday and today a very intelligent person (Lady Moncrieff) who felt both of these shocks. The first she felt in Comrie House, situated within three-quarters of a mile of the hill, from which all the shocks in Perthshire appear to emanate. The noise and concussion produced by this shock alarmed her so much that she fell from her seat on the floor, and it was a few seconds before she recovered. She was residing in Comrie House for some months last autumn, and she states that scarcely a day passed without her hearing either the rumbling noise in the earth or the moaning in the air, produced by this mysterious agent, the nature of which we are so anxious to discover. The second of these shocks Lady Moncrieff felt in Perth (about twenty-two miles east of Comrie); she was in church at the time, but it was not generally perceived by the congregation. I learn that this shock was felt also at Callendar, about fifteen miles south-west of Comrie.

I am happy to tell you that I felt one of these earthquake shocks last night at 8^h $50'$ P.M. I was in Lawers House at the time, which is (as you know) about two miles east of Comrie. The noise was like that produced by the rumbling of a cart over a pavement beneath the house; it continued for about four seconds; it was loudest in the middle. Its progress was distinctly from the westward, and at a great depth below the house. There was neither undulation nor concussion. I could form no opinion, from the nature of the noise, what was the agent which caused it.

This morning I met a gentleman who was to the south of Comrie (about two miles) when it occurred; he perceived the course of the noise to be from the north. At Ardvoirlich (about eight miles west of Comrie) the same noise was perceived.

The barometer was falling all yesterday afternoon, after having been for some days remarkably high, and before seven o'clock this morning it had fallen three-fourths of a tenth more. Yours very truly,

To the Rev. Dr. Buckland. DAVID MILNE.

Report of a Committee appointed at the Tenth Meeting of the Association for Experiments on Steam-Engines. Members of the Committee:—The Rev. Professor MOSELEY, *M.A., F.R.S.*; EATON HODGKINSON, *Esq., F.R.S.*; J. S. ENYS, *Esq., F.G.S.*; Professor POLE, *F.G.S. (Reporter).*

YOUR Committee, in reporting the progress of the experiments entrusted to their care, have the pleasure of stating that they have succeeded in accomplishing the principal object which has engaged their attention during the past year; namely, to ascertain by actual experiment the velocity of the piston of a single-acting Cornish pumping-engine, at all points of its stroke.

Unfortunately, however, from delays and accidents, arising from causes inherent in the delicate nature of the operations required and the machine used, there has not been yet time to obtain the data and work out the calculations necessary for comparing the results of experiment with those of theory, and by that means eliciting the useful information which it is hoped this comparison will offer to practical science.

The velocity-measuring machine constructed by Breguet of Paris, under the kindly proffered direction of M. Morin, was received a few months ago. It is on the same principle as those with which the beautiful experiments of M. Morin on friction were made, and which are described minutely in the works of this writer (Nouvelles Expériences sur le Frottement, or Déscription des Appareils Chronométriques). These may be referred to for a full and complete explanation of the construction and action of the machine, but the principle of it may be briefly explained as follows.

A circular disc, covered with card or paper, is made to revolve with a *uniform* motion by means of clockwork regulated by air-vanes. Plate XXV. Upon this disc, a revolving pencil, whose motion is caused by and corresponds with that of the body whose *variable* velocity is to be measured, describes a curved line: and from this curve, which results from a combination of the *variable* with the *uniform* motion, the velocity may be easily ascertained by processes and formulæ adapted to the purpose.

This beautiful and ingenious contrivance, by which spaces described in the 10,000dth part of a second may be easily discerned, is the invention of M. Poncelet, carried into execution by M. Morin.

On examining the machine, it was found necessary to make some few repairs of injuries it had received in carriage, and also some alterations to fit it for the particular purpose it was proposed to apply it to. These were done by Mr. Holtzapffel.

The instrument, when put in order, was first tried at King's College, a variable motion being given by a small carriage made to descend an inclined plane. The correspondence of the velocity shown by the machine, with that deduced by the known laws of dynamics, was such as to give great confidence in its accuracy; and after a few minor alterations suggested by frequent trials, it was removed to the East London Water Works, Old Ford, and, by the kind permission of Mr. Wicksteed, the engineer, was attached to the Cornish engine at work there. This was considered a very favourable engine to experiment upon, inasmuch as the constants involved in its working had been so accurately ascertained by Mr. Wicksteed in his previous experiments, and so amply confirmed by the long trial of the constant indicator upon it by your Committee during the years 1841 and 1842.

After several preparatory trials and adjustments, some diagrams were taken on the 8th of August, and the velocities calculated from these have been expressed in the form of geometrical curves, whose abscissæ represent the spaces passed over by the piston of the engine, and whose ordinates indicate the corresponding velocities at the different points of the stroke.

Plate XXVI. shows diagrams which represent the velocities of the piston both in the descending and ascending strokes of the engine, or as they are technically termed, the *in-door* and *out-door* strokes. The velocity of the in-door, or descending stroke of the piston, is taken from the mean of three experiments, differing very little from each other. The velocity begins from zero, accelerating as the piston descends, until at about four feet of the stroke it attains a maximum of about 10·4 feet per second. This is the point where the pressure of the steam in the cylinder has, by expanding, become exactly equal to the resistance opposed to the motion of the piston; and from this point the velocity gradually decreases as the steam becomes more attenuated, until the piston is gradually brought to rest by the exhaustion or expenditure of the whole of the *work* accumulated in the moving mass (in the shape of *vis viva*) during the early part of the stroke, while the steam power exceeded the resistance.

The velocity of the *out-door*, or pumping stroke, is much less than that of the former, the greatest velocity being only about 3·8 ft. per sec.

Plate XXVII. contains diagrams of the spaces and *times* constructed in a similar manner; the abscissæ of the curves representing, as in the former case, the spaces passed over by the piston, and the corresponding ordinates indicating the *times* in which those spaces are described.

It will be seen that the whole in-door stroke is performed in about 1½ second, and the out-door stroke in about 4 seconds. As a check to these results, the time occupied in the strokes was observed directly with a stop-watch, and was found perfectly to agree with the indications of the machine. The observed times were, as nearly as could be ascertained,

In-door stroke	1·5 second.
Short pause between the in-door and out-door strokes*	·5 ,,
Out-door stroke	4 ,,
Pause	2 ,,
Total	8 seconds.

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* This is not usual in the engines at work in the Cornish mines; in most of these the

The engine made 8 strokes in 63 seconds.

The various elements of the motion of the piston of the engine are arranged below in a tabular form.

In column B. are stated certain periods of time from the commencement of the stroke, after which periods of time the positions of the piston indicated in column A. are respectively attained.

Column C. represents the approximate velocity of the piston in each corresponding position.

It will be evident that the numbers in column A. are equivalent to the abscissæ of the curves in Plates XXVI. and XXVII., while the column B. represents the ordinates in Plate XXVII., and column C. those in Plate XXVI.

The times are given in these tables only as far as the hundredths of a second, and the velocities to the twentieth part of a foot per second; but the delicacy of the machine enables them to be calculated, when necessary, to a much greater nicety.

Tables of the Elements of the Motion of the Piston of the Cornish Pumping Engine at the East London Water Works, Old Ford.

Table I.

IN-DOOR STROKE.		
A. Spaces passed over by Piston.	B. Times in which the spaces are described.	C. Velocities acquired.
Feet.	Seconds.	Ft. per sec.
0·0	0·0	0·0
0·5	0·17	5·05
1·0	0·26	7·1
1·5	0·33	8·3
2·0	0·39	9·05
2·5	0·44	9·6
3·0	0·49	10·05
3·5	0·54	10·3
4·0	0·58	10·4
4·5	0·63	10·3
5·0	0·68	10·2
5·5	0·73	9·9
6·0	0·78	9·55
6·5	0·84	9·15
7·0	0·9	8·7
7·5	0·96	8·1
8·0	1·02	7·45
8·5	1·09	6·65
9·0	1·17	5·55
9·5	1·27	4·0
10·0	1·45	0·0

Table II.

OUT-DOOR STROKE.		
A. Spaces passed over by Piston.	B. Times in which the spaces are described.	C. Velocities acquired.
Feet.	Seconds.	Ft. per sec.
0·0	0·0	0·0
0·5	0·6	0·85
1·0	0·97	1·6
1·5	1·22	2·1
2·0	1·42	2·5
2·5	1·61	2·8
3·0	1·78	3·0
3·5	1·94	3·2
4·0	2·1	3·35
4·5	2·24	3·45
5·0	2·38	3·55
5·5	2·52	3·6
6·0	2·66	3·65
6·5	2·8	3·7
7·0	2·94	3·75
7·5	3·07	3·78
8·0	3·2	3·8
8·5	3·33	3·8
9·0	3·47	3·8
9·5	3·65	3·1
10·0	3·97	0·0

A slight oscillation of the calculated velocity is found to occur on either

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equilibrium valve is opened by the plug-rod at the end of the in-door stroke, and the engine immediately returns. But in the Old Ford engine this valve is worked by a second cataract, and therefore a short pause is often allowed.

side of the mean valve, which is given in the diagrams, and this particularly happens about the position of maximum velocity. This oscillation has its origin in an irregularity of the instrument. The plate which carries the card does not revolve with a perfectly uniform motion, the moving power being a spring, and the regulating power the resistance of the air; it is demonstrable that any variation, however slight, in the effort of the former, must result in an oscillation of the plate about a certain mean velocity corresponding to that resistance of the air which will exactly counteract the newly-acquired effort of the spring.

It is desirable to take this opportunity of acknowledging that the thanks of the Committee are particularly due to Mr. Wicksteed and his sub-engineer, Mr. Price, for the accommodation rendered at Old Ford; to Mr. Cowper, of King's College, for his kind and able assistance in the experiments; to Mr. Holtzapffel and Mr. Timme for the attention paid to the repairs and adjustments of the machine; and to Mr. Penn, of Greenwich, for the loan of an excellent indicator.

H. MOSELEY.
E. HODGKINSON.
J. S. ENYS.
WILLIAM POLE (Reporter).

London, April 1844.

Report of the Committee to investigate the Varieties of the Human Race.

THE Committee report that copies of the arranged queries have been forwarded to the remotest parts of North America, in the neighbourhood of the Rocky Mountains, to Mexico, Guiana, and to several of the States in South America; to the West Indies, to Western, Southern and Northern Africa, to different localities in Asia, the Indian Archipelago, and several of the Islands of the Pacific Ocean. They have, for the most part, been addressed to individuals, and accompanied with communications of greater or less extent, urging the importance of the subject.

Sets of queries have likewise been forwarded to scientific gentlemen, who have either visited races but imperfectly known, or have made ethnological research a part of their studies. In former years, answers have been furnished by travellers particularly acquainted with the sections of the human race to which they related. The correspondence on the subject has produced communications relating to it which have contained various points of information.

It is a gratifying fact that ethnology is now receiving systematic attention in France, Germany, and the United States, and that in this country it is also advancing.

The Ethnological Society of London, of which the commencement was announced at the meeting of the Association last year, is now regularly constituted, and it is greatly to be desired that mutual assistance may long continue to advance the study, and rescue from oblivion many interesting facts, of which without prompt attention no record will remain.

With the exception of the sums required to defray the bills for printing the queries, no demand has been made upon the grants awarded to the Committee in former years. Strict œconomy has been employed in the distribution, advantage having been taken of private opportunities and other channels requiring no expense on the part of the Association, and numerous small sums have been laid out of which no account has been charged.

Of the £15 granted last year, the sum of £7 6*s.* 3*d.* has been drawn upon the Treasurer to cover the expense of postage, lithography and stationery.

THOMAS HODGKIN.

Fourth Report of a Committee, consisting of H. E. Strickland, *Esq.*, Prof. Daubeny, Prof. Henslow *and* Prof. Lindley, *appointed to continue their Experiments on the Vitality of Seeds.*

These experiments have this year been conducted in the same manner as in former years, one portion of the seeds having been sown in the Botanic Garden at Oxford, a second at the Horticultural Society's Garden, Chiswick, and a third in Prof. Henslow's garden at Hitcham, Suffolk, instead of the Botanic Garden, Cambridge, as was at first proposed.

The Committee have this year expended 11*l.* 0*s.* 10*d.* in the purchase of seeds, materials for their preservation, and incidental expenses. Seeds of 48 additional genera have been added to the *Seminarium* at the Botanic Garden, Oxford. The Committee are indebted to Sir W. J. Hooker for a very interesting collection, consisting of 303 packets of seeds, gathered at various dates from 1800 to 1843. These have all been sown at Oxford, the quantity of each having been in most cases too small to admit of distribution. The destructive effects of time upon the vitality of seeds is well exemplified by this collection, and the following is the general result :—

Of 92 kinds gathered from 1800 to 1806, only 2 per cent. have vegetated.
... 182 ... ... 1816 ... 1823, ... 21 ... ...
... 42 ... ... in 1840 ... ... 31 ... ...

The Committee beg to renew their request for similar contributions of ancient seeds from all persons who may be interested in the inquiry.

The seeds that were gathered in 1841 and sown in 1842 have also been resown this year.

The following is a register of the results :—

Name and Date when gathered.	No. sown.	No. of Seeds of each Species which vegetated at			Time of vegetating in days.			Remarks.
		Oxford.	Hitcham.	Chiswick.	Oxford.	Hitcham.	Chiswick.	
1793.								
1. Hordeum vulgare.........	100	0	0					At Oxford the seeds were sown on the 17th of May, on a bed prepared for them in a cold frame, with the exception of those usually sown on a hot-bed. These were sown in pots and placed in gentle heat. At Chiswick the seeds were not sown till late in the season.
1841.								
2. Vicia sativa	50	43	41	3	8	13	10	
3. Daucus Carota............	100	30	39	10	11	35	42	
4. Cannabis sativa	50							
5. Pastinaca sativa	100	8	9	3	18	40	35	
6. Brassica Rapa	300	163	76	96	5	8	4	
7. Linum usitatissimum ...	150	87	39	76	6	8	8	
8. Lepidium sativum	100	97	37	61	5	8	3	
9. Polygonum Fagopyrum..	50	5	6	14	14	34	7	
10. Phalaris canariensis......	100	55	52	40	7	53	8	
11. Brassica Napus............	150	143	71	109	5	8	5	
12. Carum Carui	200	0						
13. Petroselinum sativum ...	50	7	18	17	25	63	42	
14. Trifolium ? repens	150	8	14	......	7	33		
15. Lactuca sativa	50	......	1	......	......	33		
16. Brassica oleracea	50	5	3	3	10	33	35	
17. Pisum sativum	50	42	15	37	7	35	6	
18. Faba vulgaris	25	25	22	24	11	36	21	
19. Phaseolus multiflorus ...	25	17	17	13	12	26	28	
20. Triticum æstivum	100	44	33	86	7	33	5	
21. Hordeum vulgare.........	100	86	15	66	6	13	3	
22. Avena sativa...............	100	91	57	89	7	18	5	
23. Æthusa cynapoides	100	3						
24. Antirrhinum majus	300	257	116	102	11	43	35	
25. Calendula pluvialis	200	126	135	140	9	33	8	

Name and Date when gathered.	No. sown.	No. of Seeds of each Species which vegetated at			Time of vegetating in days.			Remarks.
		Oxford.	Hitcham.	Chiswick.	Oxford.	Hitcham.	Chiswick.	
1841 (*continued*).								
26. Collinsia heterophylla	300	282	296	......	6	34		
27. Datura Stramonium	100	21	19	69	17	36	8	
28. Gilia achillæifolia	200	77	92	45	7	33	35	
29. Lasthenia glabrata	200	139	169	55	7	35		
30. Ligusticum Levisticum	100	......	35	......	......	37		
31. Pæonia mixt vars.	100							
32. Verbascum Thapsus	500	......	1	125	......	......	42	
1843.								
33. Asphodelus luteus	50	12	21	19	26	49	35	
34. Arctium Lappa	100	......	......	16	......	......	42	
35. Angelica Archangelica	100	16	3	......	30	61		
36. Ageratum mexicanum	200	......	3	9	......	......	42	
37. Aster tenella	200	26	48	110	11	35	28	
38. Allium fragrans	100	63	80	......	34	56		
39. Bidens diversifolia	150	12	10	17	9	33	35	
40. Biscutella erigerifolia	100	10	5	6	17	36	49	
41. Borkhausia rubra	100	47	54	30	5	33	7	
42. Bartonia aurea	200	75	107	......	7	33		
43. Callistemma hortensis	200	13	52	5	14	35	42	
44. Campanula medium	100	55	23	47	17	49	35	
45. Centaurea depressa	100	100	5	7	12	33	21	
46. Cladanthus arabicus	200	79	67	54	4	35	35	
47. Cleome spinosa	100	40	55	31	8	41	8	
48. Cnicus arvensis	50	......	......	4	......	......	42	
49. Convolvulus major	50	12	8	9	13	34	8	
50. Dianthus barbatus	100	100	53	89	9	43	8	
51. Echium grandiflorum	100	100	44	57	7	18	6	
52. Eucharidium concinnum	200	47	40	23	10	40	49	
53. Euphorbia Lathyris	50	6	3	11	19	43	35	
54. Gypsophila elegans	200	75	......	65	7	......	42	
55. Helenium Douglasii	200	76	116	......	9	33		
56. Hebenstretia tenuifolia	100	43	69	63	5	33	5	
57. Heliophila araboides	200	110	96	69	6	33	7	
58. Hesperis matronalis	100	72	80	70	11	33	28	
59. Hypericum hirsutum	150	......	......	8	......	......	49	
60. Kaulfussia amelloides	100	85	54	42	9	36	42	
61. Koniga maritima	200	82	61	59	5	33	6	
62. Leptosiphon androsacea	200	45	59	27	7	35	49	
63. Lunaria biennis	100	64	66	13	16	36	35	
64. Loasa lateritia	150	......	...	14	......	......	49	
65. Mathiola annua	200	59	84	60	7	34	8	
66. Melilotus cærulea	100	36	46	24	5	33	8	
67. Œnanthe crocata	100	80	86	76	40	57	42	
68. Phytolacca decandra	25	18	2	15	26	68	49	
69. Plantago media	150	56	......	64	10	......	5	
70. Polemonium cæruleum	100	67	3	55	12	44	56	
71. Rumex obtusifolium	150	47	69	110	30	46	49	
72. Silene inflata	50	37	14	7	9	40	56	
73. Smyrnium Olusatrum	100	12	45	45	27	50	49	
74. Schizanthus pinnatus	200	122	138	138	7	50	8	
75. Tallinum ciliatum	200	70	65	61	18	35	35	
76. Tigridia Pavonia	100	4	3	25	......	77	56	
77. Valeriana officinalis	100							
78. Viola lutea vars.	150	95	40	67	10	40	35	
79. Xeranthemum annuum	200	1	......	......	25			
80. Zinnia multiflora	150							

The following seeds, preserved in waxed cloth, were also resown:—

Name and Date when gathered.	No. sown.	No. of Seeds of each Species which vegetated at			Time of vegetating in days.			Remarks.
		Oxford.	Hitcham.	Chiswick.	Oxford.	Hitcham.	Chiswick.	
1841.								
81. Hordeum vulgare.........	100	90	63	83	6	30	4	
82. Avena sativa..............	100	95	41	74	6	18	5	
83. Triticum æstivum	100	65	26	48	6	33	5	
84. Vicia sativa	50	41	34	40	8	26	6	
85. Brassica oleracea	50	20	15	5	10	33	8	
86. Triticum æstivum.........	100	58	40	42	7	33	5	Preserved in open jars.
87. Lasthenia glabrata	200	100	141	29	7	33	8	

Of the 303 packets contributed by Sir W. J. Hooker,

32	kinds	were gathered	in 1800.	None of which have yet vegetated.
7	..	..	.. 1801.	Of these 6 have failed.
21	..	..	.. 1802.	One kind only has vegetated.
1	..	..	.. 1803.	This has not vegetated.
12	..	..	.. 1804.	These have all failed.
3	..	..	.. 1805.	.. ..
16	..	..	.. 1806.	.. ..
1	..	..	.. 1816.	This has also failed.
23	..	..	.. 1817.	Of these 8 have vegetated.
25	..	..	.. 1818.	.. 7 ..
18	..	..	.. 1819.	.. 7 ..
7	..	..	.. 1820.	None of these have vegetated.
48	..	..	.. 1823.	Of these 4 only have vegetated.
42	..	..	.. 1840.	.. 13 ..
47	..	..	.. 1843.	.. 22 ..
303				

The whole of these seeds were counted and sown on a moderate hot-bed, devoted entirely to them. They were, however, sown rather late in the season, so that in all probability many more of them will yet vegetate.

The following is a list of the seeds from Sir W. J. Hooker, and the results of the experiments upon them:—

Name and Date.	No. sown.	No. vegetated.	Name and Date.	No. sown.	No. vegetated.
1800.			14. Laserpitium	100	0
1. Aconitum	50	0	15. Lychnis	200	0
2. Agrostemma	200	0	16. Lunaria	16	0
3. Alyssum.....................	50	0	17. Ononis	35	0
4. Do.	150	0	18. Papaver	200	0
5. Anthericum	100	0	19. Prunella.......................	100	0
6. Aquilegia	200	0	20. Reseda	200	0
7. Clematis......................	50	0	21. Rumex	150	0
8. Cynoglossum..............	50	0	22. Saxifraga	200	0
9. Dianthus	150	0	23. Scabiosa.......................	100	0
10. Digitalis......................	200	0	24. Scandix	50	0
11. Gypsophila	150	0	25. Scutellaria	200	0
12. Heracleum...................	50	0	26. Do.	200	0
13. Isatis	100	0	27. Sisyrinchium..............	150	0

Name and Date.	No. sown.	No. vegetated.
1800 (*continued*).		
28. Sisyrinchium	200	0
29. Stachys	150	0
30. Statice	100	0
31. Teucrium	200	0
32. Trollius	10	0
1801.		
33. Campanula	1000	0
34. Colutea	75	1
35. Hyssopus	200	0
36. Iris	50	0
37. Laserpitium	100	0
38. Œnanthe	150	0
39. Scandix	50	0
1802.		
40. Actæa	50	0
41. Alyssum	100	0
42. Centaurea	50	0
43. Chelone	150	0
44. Chenopodium	200	0
45. Coronilla	25	17
46. Cucubalus	200	0
47. Galega	50	0
48. Gentiana	200	0
49. Hyssopus	200	0
50. Laserpitium	50	0
51. Myosotis	100	0
52. Polemonium	150	0
53. Potentilla	150	0
54. Prunella	100	0
55. Do.	150	0
56. Ranunculus	150	0
57. Sophora	30	0
58. Teucrium	150	0
59. Thalictrum	200	0
60. Trifolium	50	0
1803.		
61. Veronica	150	0
1804.		
62. Coronilla	50	0
63. Dictamnus	18	0
64. Digitalis	200	0
65. Matricaria	50	0
66. Papaver	150	0
67. Polemonium	150	0
68. Salvia	25	0
69. Securidaca	17	0
70. Sisyrinchium	100	0
71. Sophora	50	0
72. Uvularia	14	0
73. Viola	100	0
1805.		
74. Dianthus	200	0
75. Echium	50	0
76. Othonna	150	0
1806.		
77. Agrostemma	200	0
78. Aquilegia	100	0
79. Argemone	100	0
80. Brownea	2	0
81. Campanula	200	0
82. Gentiana	200	0
83. Do.	150	0
84. Globularia	200	0
85. Lychnis	50	0
86. Melanthium	100	0
87. Pentstemon	150	0
88. Polemonium	200	0
89. Sanicula	100	0
90. Scrophularia	150	0
91. Silene	100	0
92. Spiræa	100	0
1816.		
93. Coreopsis	50	0
1817.		
94. Æschynomene	100	1
95. Bauhinia	5	0
96. Do.	10	0
97. Cæsalpinia	6	2
98. Clitoria	50	0
99. Corchorus	50	2
100. Crotalaria	50	4
101. Dolichos	5	2
102. Elephantopus	100	0
103. Glycine	50	0
104. Hedysarum	100	8
105. Do.	100	1
106. Hibiscus	100	3
107. Justicia	100	0
108. Momordica	6	0
109. Poinciana	5	0
110. Ruellia	50	0
111. Sesamum	4	0
112. Sesbania	25	0
113. Spermacoce	150	0
114. Tallinum	200	0
115. Tamarindus	4	0
116. Triumfetta	25	0
1818.		
117. Æschynomene	50	10
118. Do.	50	18
119. Arabis	200	0
120. Banisteria	10	0
121. Bauhinia	25	0
122. Cassia	20	17
123. Do.	100	69
124. Do.	100	0
125. Do.	20	0
126. Clitoria	16	0
127. Do.	25	0

Name and Date.	No. sown.	No. vegetated.
1818 (*continued*).		
128. Clitoria	20	2
129. Crotalaria	43	0
130. Galega	100	16
131. Hedysarum	50	0
132. Do.	100	3
133. Justicia	100	0
134. Ocymum	150	0
135. Parkinsonia	11	0
136. Do.	10	0
137. Phytolacca	100	0
138. Sesbania	100	0
139. Do.	100	0
140. Spondias	2	0
141. Volkameria	25	0
1819.		
142. Adenanthera	6	4
143. Bauhinia	6	0
144. Bignonia	25	0
145. Cytisus	25	0
146. Dolichos	4	0
147. Elephantopus	100	0
148. Do.	100	0
149. Glycine	20	0
150. Lagerstræmia	12	0
151. Malva	100	17
152. Melastoma	200	0
153. Mimosa	13	0
154. Do.	25	0
155. Phaseolus	25	25
156. Sida	150	75
157. Tamarindus	3	1
158. Triumfetta	50	18
159. Do.	25	12
1820.		
160. Adenanthera	8	0
161. Aristolochia	50	0
162. Cleome	150	0
163. Dalbergia	19	0
164. Erythrina	20	0
165. Indigofera	100	0
166. Mentha	200	0
1823.		
167. Acacia	5	0
168. Do.	18	0
169. Do.	50	0
170. Do.	13	0
171. Anthocercis	25	0
172. Bellis	200	0
173. Callistachys	20	0
174. Callistemon	200	0
175. Callitris	50	0
176. Do.	50	0
177. Do.	50	0
178. Do.	4	0
179. Cassia	50	0
180. Casuarina	100	0
181. Croton	50	30
182. Cryptandra	50	9
183. Dodonæa	50	0
184. Do.	100	0
185. Do.	3	0
186. Do.	20	0
187. Elichrysum	50	0
188. Eucalyptus	5	0
189. Do.	25	0
190. Do.	7	0
191. Do.	100	0
192. Do.	50	0
193. Do.	20	1
194. Gompholobium	3	0
195. Hakea	16	0
196. Hovea	16	0
197. Isopogon	50	0
198. Leptospermum	200	0
199. Do.	100	0
200. Do.	200	0
201. Lessertia	50	0
202. Lobelia	100	0
203. Logania	14	0
204. Lomatia	50	0
205. Metrosideros	150	0
206. Do.	200	0
207. Do.	150	0
208. Mirbelia	50	0
209. Ozothamnus	100	0
210. Polygonum	150	0
211. Prostanthera	100	0
212. Pultenæa	100	2
213. Sida	50	0
214. Verbena	50	0
1840.		
215. Arctotis	100	48
216. Aspalathus	25	1
217. Athanacea	25	16
218. Brunia	150	0
219. Cheiranthus	150	0
220. Clitoria	50	0
221. Erythrina	3	1
222. Euclea	25	0
223. Glossostylis	200	0
224. Gnaphalium	200	0
225. Gnidia	100	0
226. Do.	50	0
227. Hallia	25	14
228. Hermannia	150	1
229. Indigofera	25	0
230. Do.	150	28
231. Leucadendron	25	15
232. Do.	50	4
233. Linum	100	0
234. Liparia	25	0

Name and Date.	No. sown.	No. vegetated.	Name and Date.	No. sown.	No. vegetated.
1840 (*continued*).			269. Clitoria	40	0
235. Lobelia	200	0	270. Do.	50	0
236. Mesembryanthemum	100	0	271. Do.	12	1
237. Mimosa	25	2	272. Do.	3	0
238. Do.	17	3	273. Crotalaria	50	11
239. Pelargonium	50	15	274. Deutzia	25	0
240. Do.	12	0	275. Echites	25	9
241. Phylica	25	0	276. Do.	50	0
242. Do.	17	1	277. Erythrina	7	0
243. Podalyria	100	80	278. Eugenia	1	0
244. Do.	50	33	279. Eupatorium	200	0
245. Protæa	25	0	280. Hibiscus	25	0
246. Psoralea	100	58	281. Gesneria	200	0
247. Do.	100	49	282. Ipomæa	18	8
248. Pharmaceum	100	3	283. Do.	25	19
249. Rhus	50	7	284. Do.	25	0
250. Saururia	50	2	285. Jatropha	3	2
251. Sebæa	200	0	286. Justicia	150	118
252. Senecio	100	0	287. Linum	25	17
253. Seriphium	200	0	288. Lisianthus	200	0
254. Silene	150	0	289. Do.	150	0
255. Sutherlandia	100	5	290. Melastoma	50	0
256. Trichocephalum	25	2	291. Poinciana	15	7
1843.			292. Psychotria	25	0
257. Abroma	18	12	293. Do.	50	0
258. Anacardium	1	1	294. Ruellia	25	2
259. Asclepias	25	0	295. Sapindus	2	2
260. Bermudas Cedar	25	20	296. Senecio	100	27
261. Bixa	25	0	297. Sida	25	13
262. Brunsfelsia	11	0	298. Thrinax	9	2
263. Cassia	50	5	299. Xanthoxylon	25	0
264. Do.	50	5	No Date.		
265. Do.	50	24	300. Diosma	50	0
266. Chrysobalanus	6	2	301. Stachytarpetta	100	46
267. Convallaria	2	?1	302. No name	17	0
268. Clitoria	21	0	303. No name	100	0

Of the seeds sown at Oxford in 1843, the following have vegetated since the Report for that year was submitted:—

	No. sown.	No. vegetated.
Juniperus communis	100	28
Ilex Aquifolia	100	2
Liriodendron Tulipiferum	50	1
Cotoneaster rotundifolia	20	2
Cratægus macracantha	50	1
„ punctata	50	9

W. H. BAXTER, Curator.

H. E. STRICKLAND.
C. B. DAUBENY.

On the Consumption of Fuel and the Prevention of Smoke.

By WILLIAM FAIRBAIRN, *Esq.*

THERE is perhaps no subject so difficult, and none so full of perplexities, as that of the management of a furnace and the prevention of smoke. I have approached this inquiry with considerable diffidence, and after repeated attempts at definite conclusions, have more than once been forced to abandon the investigation as inconclusive and unsatisfactory. These views do not arise from any defect in our acquaintance with the laws which govern perfect combustion, the œconomy of fuel and the consumption of smoke. They chiefly arise from the constant change of temperature, the variable nature of the volatile products, the want of system, and the irregularity which attends the management of the furnace. Habits of œconomy and attention to a few simple and effective rules are either entirely neglected or not enforced. It must appear obvious to every observer, that much has yet to be done, and much may be accomplished, provided the necessary precautions are taken, first to establish, and next to carry out a comprehensive and well-organized system of operations. If this were accomplished, and the management of the furnace consigned to men of intelligence properly trained to their respective duties, all these difficulties would vanish, and the public might not only look forward with confidence to a clear atmosphere in the manufacturing towns; but the proprietors of steam-engines would be more than compensated by the saving of fuel, which an improved system of management and a sounder principle of operation would ensure. Under the hope of the attainment of these objects, I shall endeavour to show, from a series of accurately-conducted experiments, that the prevention of smoke, and the perfect combustion of fuel, are synonymous, and completely within the reach of all those who choose to adopt measures calculated for the suppression of the one and the improvement of the other.

On a former occasion I had the honour of presenting to the British Association an inquiry into the merits of Mr. C. W. Williams's Argand furnace compared with those of the usual construction. On that occasion it was found, from an average of a series of experiments, that the saving of fuel (inclusive of the absence of smoke) was in the ratio of 292 to 300, or as 1 : 1·039, being at the rate of 4 per cent. in favour of Mr. Williams's plan. Since then a considerable number of experiments have been made by Mr. Houldsworth, Mr. Williams and others; and having occasion in the course of this inquiry to refer to these researches, it will be unnecessary for the present to notice them further than to observe, that they have been made with great care, and present some curious and interesting phænomena in the further development of this subject.

The complex nature of the investigation has rendered it necessary to divide the subject into sections, for the purpose of observing, not only the relative tendencies and connexion of each, but to determine, by a series of comparative results, the law on which perfect combustion is founded, and its practical application ensured.

Keeping these objects in view, the heads of inquiry will be—

I. The analysis or constituents of coal and other fuels.
II. The relative proportions of the furnace, and forms of boilers.
III. The temperature of the furnace and surrounding flues.
IV. The œconomy of fuel, concentration of heat, and prevention of smoke.
Lastly. General summary of results.

I. *The Constituents of Coal and other Fuels.*

The first practical inquiries into the nature and constituents of coal, are probably those of Dr. Thomson and Mr. Mushet; several others have investigated their chemical composition, but the discrepancies which exist in the varied forms of analysis render them of little value when applied to the useful arts. Dr Thomson examined four distinct species of coal, of which the following are the results :—

Quality.	Specific gravity.	Carbon.	Hydrogen.	Azote.	Oxygen.
Caking coal	1·269	75·28	4·18	15·96	4·58
Splint coal	1·290	75·00	6·25	6·25	12·50
Cherry coal	1·263	74·45	12·40	10·22	2·93
Cannel coal	1·272	64·72	21·56	13·72	

Dr. Ure also supplies an analysis of splint and cannel coal, which differ from those experimented upon by Dr. Thomson, as follows :—

Quality.	Specific gravity.	Carbon.	Hydrogen.	Azote.	Oxygen.
Splint coal	1·266	70·90	4·30	......	24·80
Cannel coal	1·228	72·22	3·93	2·8	21·05

The chief difference between the experiments seems to consist in the increased quantity of hydrogen in Dr. Thomson's cannel coal, and the total absence of oxygen, which in Dr. Ure's specimens were found in excess.

The next authority is Mr. Mushet, who analysed nearly the whole of the Welsh coals, and some others, of which the following are selected, viz.—

Quality.	Specific gravity.	Carbon.	Ashes.	Volatile matter.
Welsh furnace coal	1·337	88·068	3·432	8·300
Welsh stone coal	1·393	89·700	2·300	8·000
Welsh slaty coal	1·409	82·175	6·725	9·100
Derbyshire furnace coal	1·264	52·882	4·288	42·830
Derbyshire cannel coal	1·278	48·362	4·638	47·000

Again, we have some of the American anthracites with upwards of 90 per cent. of carbon and 3·6 of volatile matter, which correspond with nearly all the other descriptions of anthracites as given by Mr. Mushet, and more recently by Dr. Kane in his excellent work 'On the Industrial Resources of Ireland.'

In addition to the above, Dr. Fife has given some valuable experiments on coal, wherein he does not materially differ in the bituminous qualities from those of Mr. Mushet. The results of Dr. Fife's experiments were found to be in the bituminous and anthracite kinds.

	Bituminous.	Anthracite.
Moisture	7·5	4·5
Volatile matter	34·5	13·3
Fixed carbon	50·5	71·4
Ashes	7·5	10·8
	100·0	100·0

It will be observed from these experiments that considerable differences exist as to the quantity of carbon contained in each sort, and provided it be correct that the heating power of any description of fuel be a proportional of the quantity of carbon it contains; it then follows that the anthracite must be greatly superior to the bituminous qualities, which yield little more than one-half the quantity. Considerable difficulty is however encountered in the combustion of the anthracite coal, as intense heat is not only an element, but time, and a large quantity of oxygen are absolutely necessary to volatilize its products. It has been known to pass twice through an iron smelting furnace, and subjected for upwards of forty hours to the temperature of melting iron, without being affected beyond the exterior surface, having been calcined to a depth of not more than three-fourths of an inch. Such however is the obduracy of its character, that intense heat makes little or no impression upon it. To burn anthracite coal effectually, and to extract the whole of its volatile products, it must be broken into small pieces and thrown upon a furnace having a large supply of oxygen passing continually through it.

In the combustion of bituminous coal the operation is totally different, being partly friable, and splitting into fragments as the gases are evolved; hence arises the superior value of that description of fuel in almost every branch of the industrial arts.

The Newcastle, and the best qualities of the Durham coal, are exceptions to most others of the bituminous kind; they contain a much greater quantity of carbon, and are thus better fitted for the furnace. From some accurate experiments by Mr. Richardson they are found to contain—

Carbon	85·613	Specific gravity 1·278.
Hydrogen	5·205	
Azote and oxygen	7·226	
Ashes	1·956	
	100·	

The Lancashire coals approach nearer to the Newcastle and Durham than most others; and, taking the mean of some recent experiments, they contain,—

Carbon	82·95
Hydrogen	5·86
Azote and oxygen	7·93
Ashes	3·26
	100·

The specific gravity of the Lancashire coal is rather more than that of the Newcastle coal, but in other respects their constituents are much alike, with the exception of a greater proportion of ashes in the former than is found in the finer qualities of the latter.

Dr. Kane, in his recent work on the 'Industrial Resources of Ireland' (already alluded to), has given some valuable information on the properties of the Irish anthracites and other coals found in different districts of the country. He also ascertained the value of the different beds of lignite which retained their original structure of wood, which burned with a brilliant light, and left a black dense charcoal.

The constituents of two specimens analysed by Dr. Kane, gave,—

	I.	II.
Volatile matter	57·70	53·70
Pure charcoal	33·66	30·09
Ashes	8·64	16·21
	100·	100·

From the above it would appear that the œconomic value of lignite is about two-thirds of an average quality of good coal; and comparing these with other results obtained from similar lignites, two-thirds may fairly be taken as the calorific value of this description of fuel. Dr. Kane further examined a great variety of turf, and amongst others those prepared by Mr. C. W. Williams from the bogs of Cappage, Kilbeggan, Kilbaken, &c.; the elementary products of which are, according to Dr. Kane, as follows:—

	Cappage.	Kilbeggan.	Kilbaken.
Carbon	51·05	61·04	51·13
Hydrogen....	6·85	6·67	6·33
Oxygen	39·55	30·46	34·48
Ashes	2·55	1·83	8·06
	100·	100·	100·

It will be unnecessary to exemplify a greater variety of fuels, such as the different kinds of wood used in America, Russia, and different parts of the continent. In this country timber is seldom if ever used; and taking the comparative merits of the fuels already enumerated, it will be found (in assuming the quality of carbon contained in each as the measure of their respective values) that the Welsh furnace coal and the Newcastle and Lancashire coals stand pre-eminent in the order of their heating powers, either as regards their application to the furnace or to the ordinary purposes of domestic life.

The American anthracites, which in some cases contain upwards of 90 per cent. of carbon, are extensively used in that country; and assuming the mean 91·4 of Professor Johnston's experiments to be correct, and calling it at 1000, we then have an approximate value of the different fuels experimented upon, and in general use in this country.

Table of Comparative Results, showing the calorific and œconomic Value of different kinds of Fuel.

No.	Quality.	Specific gravity.	Value.
	American anthracite coal	......	1000
1	Welsh anthracite coal	1·393	981
2	Welsh furnace coal........................	1·337	963
3	Newcastle coal	1·278	936
4	Lancashire coal	1·293	900
5	Welsh slaty coal	1·409	898
6	Scotch caking coal........................	1·263	822
7	Scotch cherry coal	1·263	813
8	Scotch splint, 75·00 Scotch splint, 70·90 } Mean, 72·95 ...	1·278	799
9	Scotch cannel, 64·72 Scotch cannel, 72·22 } Mean, 68·47 ...	1·250	749
10	Derbyshire furnace coal.................	1·264	578

In the above table the œconomic value is assumed to be a proportional of the quantity of carbon contained respectively in each sort of coal, and provided the lignites and turfs are excepted, the others may safely be taken as nearly the correct value of the principal mineral fuels of the kingdom.

II. *The relative Proportions of the Furnaces, and the Forms of Boilers.*

On this part of the subject there are several points worthy of attention; namely, the proportions of the furnaces of stationary boilers of different constructions, the dimensions and position of those with exterior and interior fires, and the principle of form which approaches the nearest to a maximum calorific effect.

It is obvious that the hemispherical and waggon-shaped boilers are the best calculated to ensure abundance of space; and the furnace being detached and entirely clear of the boilers, a discretionary power is thus vested in every person choosing to experiment as to the length, breadth, or height of the hearth plate and bars which contain the fuel. Hence arise the anomalies which exist, and the innumerable theories which are advocated in every direction for improved furnaces and perfect combustion.

These discrepancies create great perplexities; and as much depends upon the management of the fire, and the will as well as skill of the engineer, it is next to impossible from such a mass of conflicting evidence to deduce anything like a correct proportional of the area of the grate-bar, and the recipient surface.

From a careful examination of some of the best-constructed boilers and furnaces in Manchester, the following results were obtained:—

No. of Boilers.	Area of grate-bars in feet.	Recipient internal surface in feet.	Recipient external surface in feet.	Total heated surface in feet.	Ratio of grate-bars to heating surface.	Remarks.
6	36·0	195·0	......	......	......	In the first six boilers the external flues could not be measured.
1	30·5	167·2	175·0	342·2	1 : 11·2	
2	36·5	201·0	267·5	468·5	1 : 12·7	
2	28·3	154·8	180·5	353·3	1 : 12·0	
2	28·7	137·3	167·0	304·3	1 : 10·8	
2	40·6	150·4	207·3	357·7	1 : 8·9	
Mean	33·4	162·1	199·4	365·2	1 : 11·1	

The ratio of grate-bar to absorbing surface is therefore as 1 : 11·1, which taken from fifteen different boilers of the best construction, and worked with considerable skill, gives a fair average of the proportions of the furnace and flue surface of each. Now, on comparing the above with the boilers at work in Cornwall, it will be found that their relative proportions are as 1 to 25; the Cornish boilers presenting from two and a half, and in some instances three times the surface exposed to the action of the fire, in the ratio of the furnace to the flue as a recipient of heat. Taking the disparities as thus exhibited, it must appear evident that exceedingly defective proportions must somewhere exist, otherwise the anomalous comparison of a small fire and a large absorbent surface could not be maintained, unless the former practice of large fires and limited flue surface had been found injurious and expensive. That a great waste of valuable fuel is the consequence of these defective proportions is abundantly manifest from the results obtained in the quantity of water evaporated by a pound of coals in each. For example, 1 lb. of good coal will evaporate in the Cornish boiler about 11½ lbs. of water, and the utmost that the best waggon-shaped boiler has been known to accomplish is 8·7 lbs. of water to the pound of coal. Hence the advantage of a small furnace and large flue surface, united however to abundance of boiler space, in order to attain a maximum effect by a slow and progressive rate of combustion. From the facts thus recorded, and the returns regularly made of the performances of the Cornish engines and boilers, it will no longer admit of doubt as to the superiority of the practice which exists in one country as compared with that in the other. Persons unacquainted with the subject have attributed the saving to the engine; but that doctrine, although in some degree correct, is no longer tenable, as experiments, and the monthly returns, unite in proving that part of the œconomy is due to the boiler; and the proportion of flue surface on the Cornish construction being so much greater, we reasonably infer that the recipient surface of the hemispherical and waggon-boilers is insufficient for the amount of fire-bar surface acting upon it.

These observations have in a great measure been corroborated by the introduction into the Lancashire districts of the cylindrical form with a large circular flue, extending the whole length of the boiler. In this flue the furnace is placed, and being confined within certain limits it no longer admits of disproportionate enlargement, but from the very nature of its construction forces old plans and old prejudices to yield to positive improvement.

The effect of the change is a progressive and improved œconomy in the consumption of coal, with a larger extent of flue surface, and, what is probably of equal value, a stronger and much more perfect boiler.

Irrespective of the changes of form and management of boilers which are in progress, it may be proper to notice a still further improvement in construction which has recently taken place, and where a still greater œconomy is effected. This is a mean between the Cornish single flue boiler and the tubular boiler; it is perfectly cylindrical, and contains two circular flues, varying from 2 feet 6 inches to 2 feet 9 inches diameter, extending throughout its whole length, as represented and explained in another place in drawings which are annexed. Towards the front end the flues are made slightly elliptical, in order to receive the furnace grate-bars, hearth-plates, &c., to give sufficient space over the fire, and to admit a free current of air under the ash-pit. On this plan it will be observed that each furnace is surrounded by water in every direction, with large intermediate spaces to allow a free circulation of the water, as the globules of heat rise from the radiant surface over the fires and the other intensely heated parts of the flues. Another advantage is the position of the receptacle for the sedimentary deposits, which do not take place over the furnace, as in the old construction, but in the lower region of the boiler, where the temperature is lowest, thus affording greater security from incrustation and other causes of an injurious tendency.

On the evaporative powers of boilers, it has already been shown, that the process to be conducted with œconomy depends upon one of two causes, or both; first, on the due and perfect proportions of the furnace; secondly, which is more probable, on the quantity of flue surface exposed to the action of heat: no doubt they are both important agents in the procuration and generating of steam, but the recipient surface is so important, that the measure of all boilers as to their œconomy and efficiency in a great degree depends upon the enlargement of those important parts. Taking, therefore, the amount of the flue surface in a boiler exposed to the passing currents of heat as a criterion of its œconomic value, we shall then have according to computation a summary of comparison as follows:—

Numbers.	Description of boiler.	Cubic contents in feet.	Area of heated surface in feet.	Ratio of the area of heating surface to cubic contents.
1	Old hemispherical boiler	420	128	1 : 3·28
2	Common waggon-boiler, without middle flue....	1044	320	1 ; 3·26
3	Waggon boiler, with middle flue	894	432	1 : 2·06
4	Cylindrical hoiler, without middle flue	789	225	1 : 3·50
5	Cylindrical boiler, with middle flue...............	579	360	1 : 1·65
6	Cylindrical boiler, with eight ten-inch iron tubes	605	567	1 ; 1·06
7	Improved boiler, with two middle flues	573	548	1 : 1·01

On a comparison of the above table, it will be seen that the generative powers of a boiler do not depend upon its cubic contents, nor yet upon the quantity of water it contains, but upon the area of flue surface exposed to the action of heat; and that the nearer the area of the flue surface approaches the cubic contents, the greater the œconomy and more perfect the boiler.

This has been proved by experiment, and also by practice in the use of No. 6 and 7 boilers, where the generative powers have been much increased, and where they approach nearer to the maximum than any other, excepting probably those with a number of small tubes, such as the locomotive, and the present construction of marine-boilers. These latter are however not so well adapted for stationary purposes, nor yet are they calculated for the attainment of other objects contemplated in this report.

It has already been stated that the relative areas of fire-grate and flue surface, taken from a series of observations, are as 1 to 11*, and in the average of Cornish boilers as 1 to 25. Now, if we take the mean of these two, and fix the ratio at 1 to 18, we shall have a near approximation to a maximum effect; and, for general practice, it will be found that such a proportion will better serve the interests of the public, and of parties employing steam-boilers, than the extreme of 1 to 25, or 1 to 30, where a great increase of boiler power must be the result. In many situations, such as the large manufacturing towns, this cannot be accomplished, and to enforce such a regulation by legislative or municipal enactments would be, to say the least, inexpedient and oppressive. Taking, therefore, the experiments, observations and other circumstances bearing upon these points into consideration, it will appear that the circular boiler, with an enlarged and extended flue surface, and accurately proportioned furnaces of about 1 to 18, is the best calculated under all circumstances for the œconomy of fuel, and those objects which have yet to be considered.

III. *The Temperature of the Furnace and the surrounding Flues.*

It is a difficulty of no ordinary description to ascertain with sufficient accuracy the temperature of a furnace. In fact every fire and every furnace is continually changing its temperature, as well as the nature of the volatile products as they pass off during the process of combustion. When a furnace is charged with a fresh supply of fuel, its temperature is lowered, and that from two causes: first, by the absorption of heat which the cold fuel takes up when thrown upon the fire; and, secondly, by a rush of cold air through the open door of the furnace. Attempts have been made to remedy these evils by the aid of machinery and continuous firing, but taking the whole of the existing schemes into account, and bestowing upon them the most favourable consideration, it is questionable whether they are at all equal (either as regards efficiency or œconomy) to the usual way of working the fires by hand. I am persuaded the latter plan is the best; and provided a class of careful men were trained to certain fixed and determined regulations, and paid, not in the ratio of the quantity of coals shoveled on the fire, but in proportion to the saving effected, we should not then have occasion for the aid of machinery as an apology for ignorance.

Operations of this kind require but a small portion of physical strength in supplying a furnace with fuel (which a machine can do), but some measure of intelligence is necessary to watch over and assist nature in the development of those laws which regulate as well as govern the process of combustion.

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* Since the above was written, I have received from my friend Mr. Andrew Murray of the Royal Dockyard, Woolwich, a series of experimental researches, some of which will be found at the close of the report.

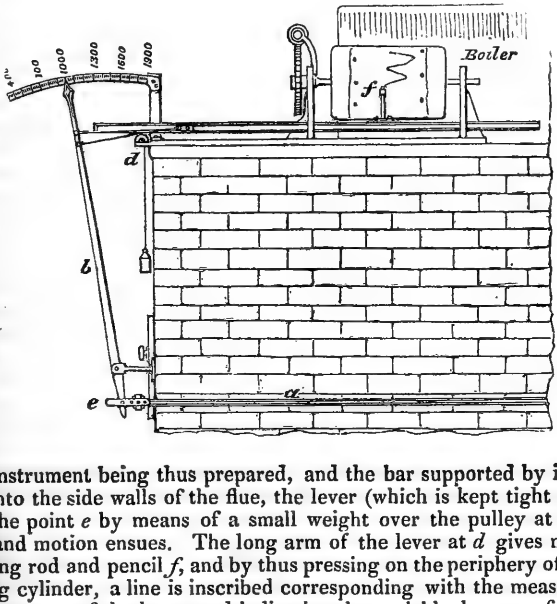
Viewing the subject in this light, it will not be uninteresting if we attempt to exhibit some of the important and exceedingly curious changes which take place in the ordinary process of heating a steam-engine boiler.

For these experiments we are indebted to Mr. Henry Houldsworth of Manchester; and, having been present at several of the experiments, I can vouch for the accuracy with which they were conducted, and for the very satisfactory and important results deduced therefrom.

In giving an account of Mr. Houldsworth's experiments, it will be necessary to describe the instrument by which they were made, and also to show the methods adopted for indicating the temperature, and the changes which take place in the surrounding flues.

The apparatus consists of a simple pyrometer, with a small bar of copper or iron (*a* in the following sketch) fixed at the extreme end of the boiler, and projecting through the brick-work in front, where it is jointed to the arm of an index lever *b*, to which it gives motion when it expands or contracts by the heat of the flue.

Pyrometer.



The instrument being thus prepared, and the bar supported by iron pegs driven into the side walls of the flue, the lever (which is kept tight upon the bar at the point *e* by means of a small weight over the pulley at *d*) is attached and motion ensues. The long arm of the lever at *d* gives motion to the sliding rod and pencil *f*, and by thus pressing on the periphery of a slowly revolving cylinder, a line is inscribed corresponding with the measurements of the long arm of the lever, and indicating the variable degrees of temperature by the expansion and contraction of the bar. Upon the cylinder is fixed a sheet of paper, on which a daily record of the temperature becomes inscribed, and on which are exhibited the change as well as the intensity of heat in the flues at every moment of time. In using this instrument it has been usual to fix it at the medium temperature of 1000°, which it will be observed is an assumed degree of the intensity of heat, but a sufficiently near approximation to the actual temperature for the purpose of ascertaining the variations which take place in all the different stages of combustion consequent upon the acts of charging, stirring and raking the fires. These are exemplified by the annexed diagrams, No. XII. and No. XXX. (Plates XXVIII. and XXIX.)

On a careful examination of the diagrams, it will be found that the first was traced without any admixture of air, except that taken through the grate-bars; the other was inscribed with an opening for the admission of air through a diffusing plate behind the bridge, as recommended by Mr. C. W. Williams. The latter, No. XXX., presents very different figures: the maximum and minimum points of temperature being much wider apart in the one than the other, as also in the fluctuations which indicate a much higher temperature, reaching as high as 1400°, and seldom descending lower than 1000°, giving the mean of 1160°.

Now, on comparing No. XXX. with No. XII., where no air is admitted, it will be found that the whole of the tracings exhibit a descending temperature, seldom rising above 1100°, and often descending below 900°, the mean of which is 975°. This depression indicates a defective state in the process, and although a greater quantity of coal was consumed, (2000 lbs. in 396 minutes in the No. XXX. experiment, and 1840 lbs. in 406 minutes in No. XII.,) yet the disparity is too great when the difference of temperature and loss of heat are taken into consideration. As a further proof of the imperfections of No. XII. diagram, it is only necessary to compare the quantities of water evaporated in each, in order to ascertain the difference, where in No. XII. experiment 5·05 lbs. of water are evaporated to the pound of coal, and in No. XXX. one-half more, or 7·7 lbs, is the result.

Taking the results thus indicated, it will appear evident that the admission of a certain quantity of atmospheric air behind the bridge operates most advantageously, inasmuch as it combines with its constituents in due proportions, and by these means the gases are inflamed under circumstances favourable to the extraction of heat and consumption of smoke. The whole process is therefore distinguishable by the fact of one diagram presenting a decreasing temperature when air is not admitted, and the other an increasing column when it is introduced. If no air is admitted, except through the grate-bars, and there happens to be a compact charge in the furnace, the consequence is that the gases pass through the flues unconsumed, and accompanied with a dark volume of smoke which is invariably present on such occasions.

It will not be necessary in this instance further to increase the number of diagrams, as No. XII., which exhibits the variations and results of the intensity of heat when air is not admitted; and No. XXX. (with an aperture of forty-five square inches constantly open) will be found encouraging features for its admission in duly regulated proportions. These two diagrams will therefore sufficiently explain the varied changes of temperature which exist, and as all the other thirty are (with occasional deviations) nearly alike, the following table of results will probably answer the same purpose as if the whole were given in detail.

TABLE OF RESULTS,

Selected from thirty Experiments obtained by Mr. Houldsworth's Pyrometer, indicating the mean temperature of the flues in a steam-engine boiler, and the effects produced by the admission of air through regulated and permanent apparatus behind the bridge.

No. of Experiments as marked on the Diagrams.	Description of coal used.	Aperture for the admission of air in square inches.	Coals burnt per hour.	Water evaporated by 1 lb. of coal in lbs.	Mean temperature in the front flue.	Relative value in the ratio of water evaporated.
12. 13 and 28.	Clifton Oldham } mean....	No air.	243·00	6·21	977°	100 : 000
9, 10, 11.	Clifton	......	278·40	5·41	973°	100 : 87·1
7 and 8.	Clifton	45	280·8	6·85	1·165°	100 : 110·3
15 to 22.	Clifton	{ Regulated by hand. }	265·8	6·94	1·122°	100 : 110·7
14.	Clifton	45	279·0	6·60	1·220°	100 : 106·2
30.	Clifton	Regulated.	279 0	6·80	1·160°	100 ; 109·5
24.	Oldham	35	243·0	6·85	1·080°	100 : 110·3
26.	Oldham	24	229·2	7·40	1·050°	100 : 119·1
23.	Oldham	Regulated.	230·4	7·70	1·070°	100 : 124·0
25 to 29.	Oldham	Regulated.	216·6	8·30	1·053°	100 : 133·6
27.	{ Mixed, half of each sort. }	......	243·0	7·20	1·060°	100 : 115·7

By comparing the results as given above, it will be found that in taking the quantity of water evaporated by 1 lb. of coal as the measure of œconomic value, the mean of nearly the whole experiments (excepting only Nos. 12, 13 and 28, where air is not admitted) is as 100 to 112·65, or about 12½ per cent. in favour of a regulated and continuous supply of air. Taking, however, the mean of experiments, 25 to 29, and comparing it with some of the others, it will be observed that a much higher duty is obtained; and having accomplished a maximum, there appears no reason for doubting why it should not be continued, and still further advantages secured by a judicious arrangement of the furnace for the admission of oxygen to the uninflamed gases, which under other circumstances would make their escape into the atmosphere unconsumed. In furnishing this supply it is not absolutely necessary to administer it immediately behind the bridge, as the same quantity of air taken through the grate-bars, or in at the furnace-doors, would nearly effect the same purpose, not only as regards the quantity of heat evolved, but also as respects the transparency of the gases and the consequent disappearance of smoke.

Mr. Houldsworth estimates the advantages gained by the admission of air (when properly regulated) at 35 per cent., and when passed through a fixed aperture of 43 square inches, at 34 per cent. This is a near approximation to the mean of five experiments, which, according to the preceding table, gives 33½ per cent., which probably approaches as near the maximum as can be expected under all the changes and vicissitudes which take place in general practice.

On a cursory view of the subject, it is obvious that the quantity of air necessary to be admitted will greatly depend upon the nature and quality of the fuel used. In a light burning fuel, such as splint and cannel coal, less air will be required, as the charge burns freely with clear spaces between the grate-bars, and attended by less risk of cementation than the caking coal, which in some cases completely seals the openings, and thus deprives the fuel of that quantity of air necessary for its combustion; under such circumstances a permanent opening will be found exceedingly efficacious, and that more particularly when the heat vitrifies the earthy particles of the coal, and forms clinkers on the top of the grate-bars. In the use of this description of fuel the permanent apertures are of great value.

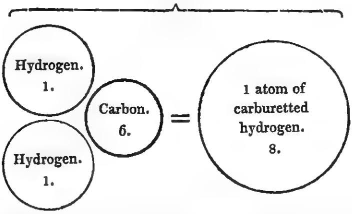
IV. *The Œconomy of Fuel, Concentration of Heat, and Prevention of Smoke.*

Irrespective of the intensity of heat, form of boilers, and quality of fuel, there are other conditions connected with the phænomena of combustion which require attentive consideration before that process can be called perfect, or before œconomy or the prevention of smoke can be attained. It is perfectly clear, that although we may possess abundance of excellent fuel, and a perfect knowledge of all the elements necessary for its combustion, yet we are still far short of attaining our object, unless a regard to œconomy is strictly kept in view. A manufacturer may have well-proportioned boilers, excellent furnaces, and good fuel; but with all these advantages he will not succeed, unless the whole of the elements at his command are properly and œconomically combined, and that upon fixed laws already determined for his guidance. Count Rumford, in his admirable Essays on the Œconomy of Heat, truly observes, that "no subject of philosophical inquiry within the limits of human investigation is more calculated to excite admiration and to awaken curiosity than fire, and there is certainly none more extensively useful to mankind. It is owing, no doubt, to our being acquainted with it from our infancy that we are not more struck with its appearance, and more sensible of the benefits we derive from it. Almost every comfort and convenience which man by his ingenuity procures for himself is obtained by its assistance, and he is not more distinguished from the brute creation by the use of speech, than by his power over that wonderful agent."

Such was the opinion of one of the most eminent philosophers of his time, and such were the pertinency of his remarks and the depth of his researches, that had he lived in the present instead of the close of the last century, he would not only have extended and enlarged our views on the management and œconomy of heat, but he would have expressed astonishment at the increase, the immense extent of expenditure, and the lavish and culpable waste of fuel by which we are surrounded on every side. It is true we have some exceptions, such as those in Cornwall and some parts of the continent, where fuel is expensive; but taking the aggregate, it might be said, without fear of contradiction, that if one-half of the fuel now used were properly applied, it would perform the same service, and afford the same comforts as we now derive from the whole of our mineral products. This is a great reflection upon the philosophy as well as the œconomy of the age, and I think it can be shown that one-half the fuel now wasted might be saved with great advantage to individuals, and with increased benefit as well as comfort to the public. The wasteful expenditure which exists does not arise so much from ignorance as from prejudice and a close adherence to old and imperfect customs. We all, more or less, venerate the works of antiquity, but unfortunately we forget to draw the distinction between what is really ancient and sound in principle and what is imperfect in practice. Hence follows a blind adherence to established usage, and the consequent propagation of all the defects as well as the perfections of the system. Now this state of things should not exist, as we have the experiments of Watt, Rumford, Davy, Parkes, and many others before us, and adding to these the excellent treatise of Mr. C. W. Williams on the combustion of coal and prevention of smoke, we are enabled by these means to establish a sound and much more perfect as well as œconomical system of combustion. Keeping these objects in view, we shall endeavour to determine some fixed principle on which may be founded the prevention of smoke, concentration of heat, and œconomy of fuel.

It is well known that in practical operations there is no combustion without oxygen as its supporter, and as that important element cannot be procured for general purposes without the other constituents of atmospheric air, it follows, that in order to effect combustion, a regular supply of this compound must be constantly at command. Now it is not the facility, but the control and regulation of the supply of air which requires attention, and on this point of the inquiry we must refer to the researches of Mr. C. W. Williams, where, in speaking of "gaseous combinations," he shows that much depends upon the conditions and proportions in which the gases evolved during the process of combustion combine with the oxygen of the air. And in order to effect this, it is necessary for those entrusted with the management of furnaces to know the "equivalents" or definite proportions under which these combinations take place. On this head it will be sufficient to observe, that the principal gases evolved from coal in a state of combustion are carburetted hydrogen, bicarburetted hydrogen, and some others, such as carbonic acid gas, carbonic oxide, &c., the properties of which it is not requisite on this occasion to investigate, but to confine the inquiry to the union of carburetted hydrogen, bi-carburetted hydrogen, and atmospheric air. Following, therefore, the Daltonian theory, it will be found that the constituents of one atom of carburetted hydrogen consist of the following symbols, each representing an atom, and the figures the weight:—

Carburetted hydrogen.

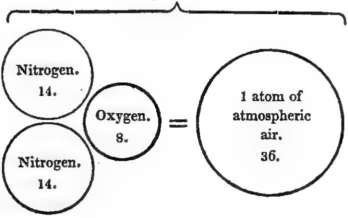


Carburetted hydrogen is therefore composed of 2 hydrogen and 1 carbon = 1 carburetted hydrogen. In weight 2 hydrogen + 6 carbon = 8 carburetted hydrogen. The constituents of bi-carburetted hydrogen are 2 hydrogen and 2 carbon = 1 bi-carburetted hydrogen. In weight, 2 hydrogen and 12 carbon, or 2 + 12 = 14 bi-carburetted hydrogen.

These are the two principal gases which require attention, and as the oxygen of the air is an element that cannot be dispensed with, the object of our next inquiry will be into the quantity and constituents of atmospheric air.

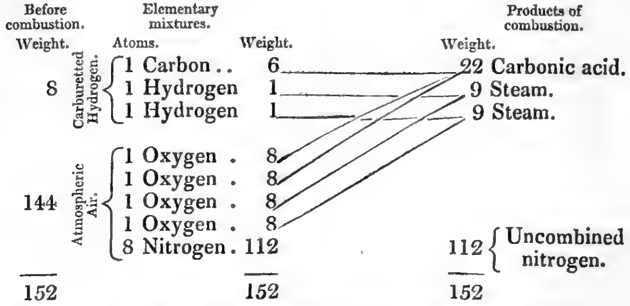
According to the best authorities atmospheric air is found in the proportion of 1 oxygen and 2 nitrogen, or according to Mr. Williams (adopting the figures as representing the weights as before),—

Atmospheric Air.

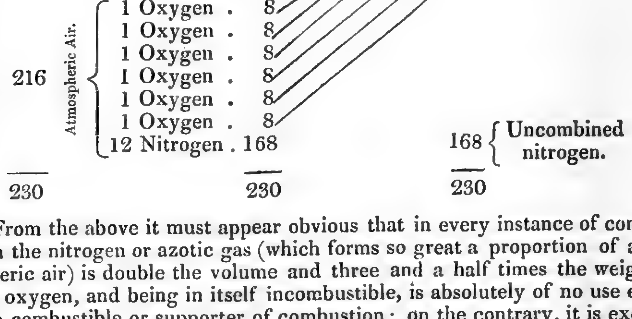


Having thus ascertained the constituents and equivalents in which the combustible and incombustible gases combine, it will easily be determined what quantity of atmospheric air will be necessary to support and effect perfect combustion of the fuel of which the above are constituents. For this purpose it will be observed that a very considerable quantity of air must be brought in contact with the incandescent fuel before the process of combustion can be effected, and having already determined the constituents of each, we must next determine the quantity of air required for the purpose of supporting the entire combustion of the gases without producing a diminution of the temperature in the process.

On this part of the subject several able authorities may be quoted; but taking that of Professor Brande (as given by Mr. Williams), the following diagram indicates the relative weights of the atoms both before and after combustion:—



Again, for the olefiant gas, or bi-carburetted hydrogen, we have—



From the above it must appear obvious that in every instance of combustion the nitrogen or azotic gas (which forms so great a proportion of atmospheric air) is double the volume and three and a half times the weight of the oxygen, and being in itself incombustible, is absolutely of no use either as a combustible or supporter of combustion; on the contrary, it is exceedingly injurious, as not combining with the other gases; it reduces the temperature, and thus deprives the fuel of a great portion of its heat, which otherwise would (as in the case of the Bude light) have given much greater intensity of heat and greater brilliancy in its illuminating powers. Finding it however impossible to separate the nitrogen from the oxygen of the air (for general purposes), we must take the mixture as it is, and instead of using 1 atom of oxygen, we must take 2 of nitrogen along with it, and as 4 atoms of oxygen and 8 of nitrogen are required for the saturation of 1 atom of carburetted hydrogen, it follows that four times the quantity of air in volume and 144 of weight will be necessary for that purpose. Again, for the saturation of 1 atom of bi-carburetted hydrogen, 6 atoms of oxygen and 12 of nitrogen, in weight 216, are wanted, which, added to the previous quantity in combination with the carburetted hydrogen, the whole supply of air will therefore be $4 + 6 = 10$ volumes of atmospheric air to one of coal-gas. Ten to one is therefore the true proportion of atmospheric air required for attaining perfect combustion, and for reducing the gases to their ultimate products of carbonic acid and water.

Having determined the conditions and relative proportions of the gases and their supporters in a state of perfect combustion, it will be seen that in order to ensure œconomy and effect in the combustion of fuel, a large and copious supply of air must be admitted to the furnace, and that in the ratio of 10 volumes of air to 1 of coal-gas. It is difficult to determine the exact quantities evolved from every description of fuel, and probably equally so to supply its equivalent of air; but in order to attain certainty in this respect, let the openings be made sufficiently large, and by a little attention to the quality of the fuel and quantity of air required for its combustion, the apertures may be contracted till such time as a mean average and a close approximation to the maximum effect are obtained.

The concentration of heat is a consideration of much importance in the œconomy of the steam-engine and the industrial arts; and as much depends upon its preservation, it may be useful in this place to direct attention to a few self-evident facts, which if properly attended to will lead to considerable saving in the use and application of heat.

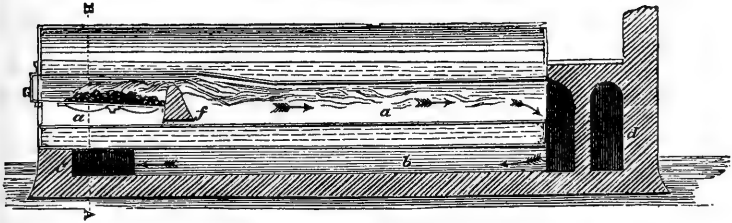
It cannot be doubted, that after having applied the rules, conditions and proportions requisite for the creation of heat, the whole of our knowledge may become obsolete unless the heat thus generated be closely preserved, and if I may use the expression, *kept warm*. It would be worse than useless to study œconomy in one department, so long as a lavish expenditure goes on in another; and having once acquired a given quantity of heat, the next thing to be done is to retain and prevent its escape. Caloric is a body which radiates in all directions, and unless surrounded with warm clothing, or non-conducting substances, it is sure to disappear; and although tightly bottled up, it sets at defiance the closest and hardest metals, and frequently escapes through the pores of the thickest iron and steel. Unlike gases and fluids, such as air and water, it is only kept within bounds by an envelope of soft wool or pounded charcoal, and the highest temperature of heat may sometimes be retained by a solid compact mass of lime and baked clay. This is strongly exemplified in the construction of ovens and furnaces, which, taken as a rule, will establish the principle on which heat can be preserved without diminution till it is used. For this purpose we should recommend the flues and furnaces of boilers, and other fires, to be closely encased with good building material adapted for the retention of heat, and all steam-boilers to be well-covered and clothed, so as to prevent (as much as possible) the escape of heat in that direction; and for steam-engines, that all the steam pipes, cylinders, &c. should be closely enveloped in a thick coating of felt, canvas or wood, and afterwards well-painted. These precautions being taken, the effects will soon become visible in a saving of 15 to 20 per cent. of fuel, *On the Prevention of Smoke.*—The ultimatum of this inquiry is twofold; first the combustion of fuel, and secondly the prevention of smoke. In the preceding investigation we have endeavoured to establish the laws which regulate and govern the combustion of fuel, and in that attempt we have also endeavoured to show the difference between perfect and imperfect combustion. Now perfect combustion is the *prevention of smoke,* and whenever smoke makes its appearance we may reasonably infer that imperfect combustion, and probably want of attention to a few simple rules is the cause. We have already inculcated these rules, and shown from well-known chemical facts, that 1 atom of coal-gas requires 10 atoms of atmospheric air for its complete combustion; *when that quantity is at its maximum or in excess there is no smoke, when it is different smoke is invariably present.* It therefore follows, that in order to render the residue of the products of combustion transparent, or "*smokeless,*" a supply of air amounting to ten times that of the gases evolved must be admitted. Should it exceed that quantity the effect will not be smoke, but an additional expenditure of fuel to supply the loss of heat which this excess of air would require for absorption, rarefaction, &c. Hence the necessity which exists for power to regulate the admission, if not the exact, at least an approximate quantity of air. On the other hand, should the supply be deficient in quantity (which is often the case), a dense volume of smoke is then visible, accompanied with all the defects and annoyances of imperfect combustion.

The variable changes which accompany perfect and imperfect combustion are not only visible, but may be proved by experiment. Let any person apply his hand to the tube of an Argand gas-burner, and he will find that the instant the aperture is partially closed the flame immediately becomes elongated; and instead of a clear brilliant light, a dull red flame, with a dark volume of smoke, is the result. This shows the effect of a diminished supply of air; and the same may be applied to a steam-engine furnace, when imperfectly supplied with oxygen, when the gases pass off in opake volumes unconsumed, and where a considerable portion of heat is entirely lost from that cause. It has been stated that we cannot have fire without smoke; but this is not the case in steam-boilers, as a well-constructed furnace properly managed furnishes many examples where bituminous coal is consumed in large quantities and with little if any appearance of smoke. If coal were double the price, it is more than probable that a great improvement would shortly present itself, and that not exclusively in the suppression of the smoke nuisance, but in a further extension of those duties wherein œconomy becomes a leading feature in the attainment of these objects. It is therefore futile to urge difficulties which have already been overcome, and where in many instances "the prevention of smoke" is accomplished with perfect ease, and with great benefit to the parties concerned. In attempting the total suppression of this nuisance, two important considerations require to be attended to as essential; the first of which is *abundance of boiler space,* and the second a *sufficient supply of air.* For the last of these we have already given sufficient instructions for its admission; and for the first we could not furnish a better rule for the capacity and power of boilers than that which applies to the steam-engine, namely that of raising 33,000 lbs. one foot high in a minute. For example, suppose a steam-engine of 50 horse nominal power to be worked according to the indicator up to 80 horse, which taken at 33,000 lbs. one foot high in a minute, we have then to calculate, from data already given, the size of boilers required. Using these precautions, and never loading the steam-engine beyond its nominal power without enlarging the boilers in proportion, the effects will be an almost total suppression of smoke and a saving of fuel.

To all those practically acquainted with the subject, it is well known that a boiler of limited capacity, when overworked, *must be forced, and this forcing is the gangrene which corrupts and festers the whole system of operations.* Under such circumstances perfect combustion is out of the question, and any attempt at œconomy is, as heretofore, a complete failure. I have been the more particular on these points from having witnessed innumerable errors and mistakes in this respect, and it cannot be too forcibly impressed upon the minds of the public, that a LARGE BOILER is one of the essentials absolutely necessary for the acquirements already insisted upon.

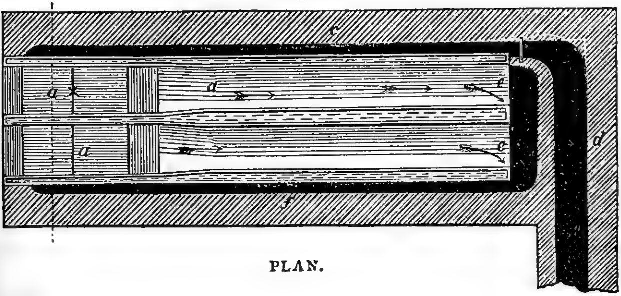
IMPROVED STATIONARY BOILER.

Fig. 1.



SECTIONAL ELEVATION.

Fig. 2.



PLAN.

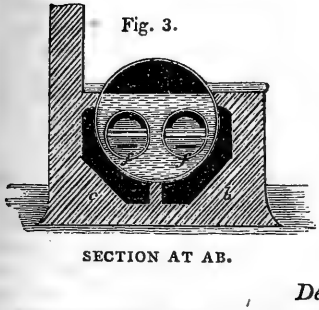


Fig. 3.

SECTION AT AB.

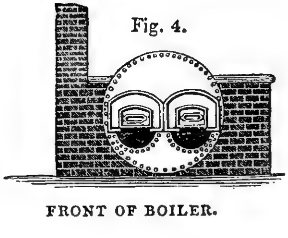


Fig. 4.

FRONT OF BOILER.

Description.

Figs. 1 and 2 represent a plan and longitudinal section of the boiler with double flues and double furnaces, and figs. 3 and 4 a transverse section and end view. In these representations it will be seen that the gases emitted from the furnaces *a*, *a* × are conducted along the internal tubes into the return flue *b*. From *b* they cross under the boiler below the ash-pit into the flue *c*, and from thence along the opposite side of the boiler into the main flue *d*, which communicates with the chimney. From this description it will be observed that the gases do not unite until they have reached *e e* at the end of the boiler. At this point a change immediately takes place in the gaseous products, and that from one of two causes, as follows. Suppose the furnace *a* × to be newly fired, and the fuel in it in a perfectly incandescent state; it then follows that the gases passing from *a* will not only be different in their constituents to those from *a* ×, but they are at a much higher temperature; and both furnaces having received air as a constant quantity through the fixed apertures *ff*, it will be seen that in the event of a surcharge of air on one side, and a diminished supply on the other, that their extremes are neutralized by the excess of oxygen thus introduced and the increased temperature which effects ignition at the point *e*, where combination takes place. All that is therefore necessary is to replenish the fires alternately every 20 minutes in order to effect the combustion of the gases without the least appearance of smoke. These and the increased recipient surface are the leading properties of this boiler, which, compared with others having single flues, is found to be greatly superior either as regards the combustion or œconomy of fuel.

General Summary of Results.

In briefly recapitulating the experiments, observations and results obtained, it will be seen that in the procurement and employment of heat, a number of important matters have to be considered.

First, the quality and properties of the fuel used.

Secondly, its treatment in the furnace, and the supply of air requisite for its combustion.

Thirdly, the form of boilers, and the extent of their absorbent surfaces.

Fourthly, the concentration and œconomy of heat. And

Lastly, the prevention of smoke.

These have been treated upon in their respective order, and all that now remains is to collect them into form, and draw such conclusions as will enable practical men to understand and apply the means necessary for their fulfilment.

From what has been stated, and from the many facts collected and experiments made, it will appear conclusive that a much better and more comprehensive system of combustion can be accomplished; and by attention to the following results, great and important advantages may be obtained.

Amongst the varied species of fuel enumerated in the foregoing experiments, there will be found ten different sorts of coal, each exhibiting its peculiar properties and compounds. For the sake of brevity and deduction, these may be divided into three kinds, namely the anthracite, the bituminous and splint qualities. Of the anthracite we have little experience beyond a knowledge of its properties and the absence of smoke. It is a coal which requires a large supply of oxygen for its combustion, and instead of the furnace usually employed for the consumption of the bituminous kind, it would require one possessing the power of a reverberatory or a strong blast acting upon it, and that under circumstances of a minute division of its parts.

The bituminous kind is however what we have most to do with, and on reference to its constituents, it will be seen that a specific quantity of atmospheric air is absolutely necessary for its combustion, amounting, as already stated, to 10 times the volume of gases it contains. Now, from a number of well-conducted experiments on the waggon-shaped, and the improved boilers with double flues, it was ascertained that the following proportions of permanent openings for the admission of air behind the fire-bridge were the nearest approach to perfect combustion*.

Summary of Results obtained from 17 Experiments with fixed apertures for the admission of air behind the bridge of two 40-horse power Boilers.

Description of Boilers and number of Experiments made.	Power of Boilers in horses.	Area of grate-bars in feet.	Area of permanent aperture in square inches.	Number of square inches of aperture to every foot of grate-bar.
Waggon-boiler, mean of 10 experiments.........	40	28·0	46·3	1·64
Double furnace boiler, mean of 7 experiments.	40	23·4	18·5	·46
Mean.	40	25·7	32·4	1·05

It therefore appears that about 26 square feet, and 32½ inches of permanent aperture for the admission of air, is the mean of the old and improved boilers.

This proportion must not however be taken as a criterion for every boiler, as much depends upon the principle on which they are constructed, and it will be safer to adopt the mean results of the experiments as shown in the table, than to apply them without exception to every description of boiler and furnace. Taking therefore the mean of the whole experiments, we may safely administer the following supply of air behind the bridge.

For cylindrical waggon-shaped and every description of boiler of the usual construction, give permanent opening for the admission of air of 1¼ square inch to every square foot of grate-bar; and for every square foot of grate-bar surface in the double furnace and double-flued boiler, give half a square inch, or ·5 for the same purpose.

Practically considered, this will be found a near approximation to the correct quantity of air required for the support of effective combustion in each, and provided necessary attention is paid to considerations involving the consumption of bituminous coal, of different kinds, we may reasonably infer a greatly improved process in the use and absorption of our mineral fuels.

In the combustion of splint and slaty coal, a different treatment will be required as respects either the anthracite and the bituminous kinds; the one is obdurate and hard, the other is compact, and in some instances liquefies like pitch. Now the splint and slaty specimens burn open and rapid, and therefore require less air, exclusive of what is taken through the grate-bars.

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* It is due to Mr. John Wakefield (formerly of Manchester, now of Farnworth near Bolton) to state, that he was amongst the first who turned his attention to the admission of air at the bridge, behind the furnace, for the purpose of consuming the smoke as it escaped into the flues. His first furnace was constructed on a plan of his own, having a hollow bridge closed at the top, and thus rendering it an air-chamber connected with openings on each side of the furnace. On this plan the air was heated by the passing currents, and by a communication from the air-chamber to an opening in the arch-plate over the furnace door, the air thus rarefied was forced downwards, by the form of the opening in the plate, direct upon the fire. A variety of other schemes were tried by Mr. Wakefield, some of them successfully; and it is only justice to that gentleman to state, that a considerable portion of his life was devoted to improvements in steam-boiler furnaces, and the abatement of a nuisance which at that period (nearly thirty years ago) was justly complained of.

In some cases it may however be necessary to overtake and effect the ignition of such gases as may escape over the bridge unconsumed, and for this purpose, in some descriptions of light coal, it may be desirable to admit about half the quantity of air used in the combustion of the bituminous kinds.

The ultimate results are, therefore,—

A perfect knowledge of the properties of the fuel used, and judicious management in working the fires.

An increase in the area of recipient surface of the boiler in the ratio of the furnace as 1 to 18, or what is the same thing, a reduction of the grate-bar surface to that proportion.

A constant supply of air (through a fixed aperture) of $1\frac{1}{4}$ square inch to every foot of grate-bar in common boilers, when burning bituminous coal; and half that area when using splint coal. These openings should however be regulated in the first instance by hand, until the mean or maximum effect in reference to the fuel is obtained.

A complete covering of felt, or some other non-conducting substance, to be applied to the exterior parts of the boiler, and the flues to be well-protected on all sides from the external air.

On a strict observance of these rules will depend the question of *smoke or no smoke,* and also whether an important œconomy in the use of fuel shall or shall not be effected. We are assured, from the experimental facts already recorded, that both these objects can be accomplished, and it rests with the community to determine how far they shall be carried into effect.

At the time of entering upon this investigation, it was my intention to have confined it within exceedingly narrow limits: it was however found to increase in interest as I advanced; and from the nature of the subject, and the number of considerations connected therewith, I became involved in a long and important inquiry; an inquiry progressively developing new features, and admitting of no curtailment except only in such matters as did not directly bear upon the subject. As it is, I fear I have but imperfectly discharged the duty entrusted to my care: it is however done honestly; and trusting to future developments in the hands of superior writers, I close the report under the impression that the preceding investigations may direct public attention to the extension of our knowledge and improvement of our practice in the combustion of fuel and the prevention of smoke.

Manchester, Nov. 30, 1844.

Note by Mr. Fairbairn, *being an Appendix to the preceding Report.*

During the progress or about the close of the above report, I found that my friend and former pupil Mr. A. Murray had communicated a paper on a similar subject to the Institution of Civil Engineers, entitled "The Construction and proper Proportion of Boilers for the Generation of Steam."

Mr. Murray has had many opportunities of judging of the best forms and proportions of marine boilers, and, from the facilities afforded in his professional avocations at the Royal Dockyard, Woolwich, I am induced to quote a few of his observations relative to the area of the flue, bridge, chimney, &c., which have in some degree been omitted in the preceding report. In treating of the quantity of air entering into combination with the volatile products of pit coal, Mr. Murray states, that "The quantity of air chemically required for the combustion of 1 lb. of coal has been shown to be 150·35 cubic feet, of which 44·64 enter into combination with the gases, and 105·71 with the solid portion of the coal. From the chemical changes which take place in the combination of the hydrogen with oxygen, the bulk of the products is found to be to the bulk of the atmospheric air required to furnish the oxygen, as 10 is to 11. The amount is therefore 49·104. This is without taking into account the augmentation of the bulk due to the increase of the temperature. In the combination which takes place between the carbon and the oxygen, the resultant gases (carbonic acid gas and nitrogen gas) are of exactly the same bulk as the amount of air, that is, 105·71 cubic feet, exclusive, as before, of the augmentation of bulk from the increase of temperature. The total amount of the products of combustion in a cool state would therefore be $49·104 + 105·71 = 154·814$ cubic feet.

"The general temperature of a furnace has not been very satisfactorily ascertained, but it may be stated at about 1000° Fahrenheit, and at this temperature the products of combustion would be increased, according to the laws of the expansion of aëriform bodies, to about three times their original bulk. The bulk, therefore, of the products of combustion which must pass off must be $154·814 \times 3 = 464·442$ cubic feet. At a velocity of 36 feet per second*, the area, to allow this quantity to pass off in an hour, is ·516 square inch. In a furnace in which 13 lbs. of coal are burnt on a square foot of grate per hour, the area to every foot of grate would be $·516 \times 13 = 6·708$ square inches; and the proportion to each foot of grate, if the rate of combustion be higher or lower than 13 lbs., may be found in the same way.

"This area having been obtained, on the supposition that no more air is admitted than the quantity chemically required, and that the combustion is complete and perfect in the furnace, it is evident that this area must be much increased in practice where we know these conditions are not fulfilled, but that a large surplus quantity of air is always admitted. A limit is thus found for the area over the bridge, or the area of the flue immediately behind the furnace, below which it must not be decreased, or the due quantity could not pass off, and consequently the due quantity of air could not enter, and the combustion would be proportionally imperfect. It will be found advantageous in practice to make the area 2 square inches instead of ·516 square inch. The imperfection of the combustion in any furnace, when it is less than 1·5 square inch, will be rendered very apparent by the quantity of carbon which will rise unconsumed along with the hydrogen gas, and show itself in a dense black smoke on issuing from the chimney. This would give 26 square inches of area over the bridge to every square foot of grate, in a furnace in which the rate of combustion is 13 lbs. of coal on each square foot per hour, and so in proportion for any rate. Taking this area as the proportion for the products of combustion immediately on their leaving the furnace, it may be gradually reduced, as it approaches the chimney, on account of the reduction in the temperature, and consequently in the bulk of the gases. Care must however be taken that the flues are nowhere so contracted, nor so constructed, as to cause, by awkward bends, or in any other way, any obstruction to the draught, otherwise similar bad consequences will ensue."

From this statement it would appear, that 26 square inches of area over the bridge is about the correct proportion for the combustion of 13 lbs. of coal per hour on each square foot of grate-bar. Now these proportions are rather more than is given in stationary boilers; as the mean of a number of experiments, taken where the combustion was most perfect, gave about 18 square inches over the bridge, and about 28 square inches as the area of the flues to every square foot of grate-bar.

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* See Dr. Ure's experiments, read before the Royal Society, June 1836.

These data may not at first sight appear important; they are however of great value in practice, as the œconomy of the fuel and the efficiency of the furnace in a great measure depend upon the height of the bridge behind, which operates as a retarder of the currents in the same way as the damper is used for checking the draught of the chimney in the flues.

Mr. Murray further treats of the temperature of the furnace, flues, &c., but these points having already been experimented upon and fully discussed in the report, it will not be necessary to notice them in this place.

William Fairbairn.

Report concerning the Observatory of the British Association, at Kew, from August the 1*st*, 1843, *to July the* 31*st*, 1844.

By Francis Ronalds, *Esq., F.R.S.*

In August of last year (1843) I drew up a short account of the electrical observatory here, as fitted up and supplied with instruments under my direction, and principally in accordance with a plan which I had in November 1842 stated to Professor Wheatstone.

That account was annexed to a journal of about one month's electrical observations made therewith, and the meteorological journal commencing in October 1842.

From August 1843 to the present time a similar electrical journal has been maintained with all the attention to accuracy which our ways and means have permitted, and it has been presented to the Association in a condensed tabular form embodied with the other meteorological observations made here.

But as the above-mentioned statement may be deemed not quite sufficient for a due appreciation of the circumstances under which our journal has been kept, as I have since made a few variations in and additions to the collection of instruments, given to the journal a different form*, and instituted a few test and other experiments, it seems expedient to comprise in this report, first, a short description of the building itself, and of the whole meteorological apparatus employed; secondly, some necessary explanations, and a specimen of the journal; thirdly, a brief statement relative to all the experiments (of *any* moment) which have been made.

I. *Description of the Observatory and of Instruments used for the Observations.*

The Building.

The position, form, &c. of the structure (Plate XXX. fig. 1), are certainly very favourable to electrical meteorology. It was erected for His Majesty George III. by Sir William Chambers, in about the year 1768, in the old Deer Park, Richmond, upon a promontory formed by a flexure of the river, its least distance from which is 924 feet. The nearest trees (elms) are about 13 feet lower than the top of the conductor. Some elms more distant average about 13 feet lower, and the trees of various kinds, as elm, beech, poplar, &c., on the bank of the river, about 8 feet lower. Innumerable high trees exist in the royal pleasure-grounds, the nearest being about half a mile distant.

The height of the top of the conductor above the level of the sea is about feet; above the river, at low water, about 83 feet, and above the top of the dome 16 feet.

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* As nearly like the Astronomer Royal's as possible.

The neighbourhood of the river and the rather marshy state of the land near the building cause sometimes very dense and interesting fogs*.

The foundation is of an extremely solid and costly kind. The basement, partly sunk in an artificial mound, is occupied by Mr. Galloway's family and that of Mr. Cripps †.

The principal entrance is by a flight of stone steps, on the north side, into a fine hall equal to and corresponding with the apartment A. B is a room which was built for the great mural quadrant, and has shutters, b^1 b^2, in the roof, &c., and in the meridian of the two obelisks near the river. [The northern window of this apartment is used for the exposure of thermometers and hygrometers.] The other wing (C) consists of the (former) transit-instrument-room, with its sliding shutters, a small apartment for an azimuth instrument, and part of a circular staircase. The north upper room, like and equal to D, is to be used as a bed-room. D is appropriated as a sort of laboratory, library, study, experimental room, &c. The central rooms (A, D, &c.) are entirely lined with glass cases, which formerly contained philosophical instruments, objects of natural history, &c. (many of the cases now subject to dry rot, but still may prove very convenient), and all the rooms are provided with stoves. The flat leaden roof of the front and back rooms (D) is surrounded by a balustrade, &c. It is entered upon by convenient stairs and a door, and serves admirably for viewing the sky, and for the reception of some instruments, &c. The smoke of the chimneys is sometimes annoying, and perhaps a little detrimental; but I think that the smoke and the hot air scarcely ever rise so high as to interfere with the electrical indications of the principal conductor; an almost imperceptible breath of wind carries them away horizontally.

The small equatorial apartment (E) is composed chiefly of wood covered externally by sheet copper; it is erected partly upon an extremely solid wall extending from the foundation of the whole building. The dome (e) was moveable round its axis by means of beautiful, but now scarcely efficient, internal rack-work, &c. It had above, the usual opening with sliding shutters, and below, a kind of door, corresponding with them and opening upon the plinths (f)‡: this room is now our principal

Electrical observatory, which has been thus adapted and furnished. [The parts of fig. 2 in diagonal shading represent a sectional plane cutting the axis of the dome; the other parts are in projection.]

Through the centre of the dome A A A has been cut a circular aperture, and in that is fitted a smooth mahogany varnished cylinder, $a^1 a^1$. B B is a window, the frame of which formerly carried the sliding shutter; and g (fig. 1) are steps by which the top of the dome may be reached.

G G G, fig. 2, is a strong cylindrical pedestal (the upper part of which becomes a warm and dry closet for little electrical articles). G^1 G^1 is a stage surrounding G, upon which the observer mounts by the steps G^2.

C C C (fig. 2) and h (fig. 1) is the *safety conductor*, composed of a leaden strap soldered to the leaden roof of the lower apartments, which roof is connected by various little straps and solderings with leaden pipes (h^1 h^2, fig. 1), in good conducting communication with the drains, pond, &c.

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* Electric signs are usually higher upon bridges than elsewhere, all other things being equal in serene weather, and fogs present remarkable electric phænomena.

† An apartment, of which X is the window, was frequently used by His Majesty as a turning-room. We want the lathe very much.

‡ It may be as convenient to other observers as to Mr. Galloway and myself to know, that these sloping plinths or steps are in frosty weather very dangerous.

The Principal Conductor, &c.

The principal conductor, D D (fig. 2), and H (fig. 1), is a conical tube of thin copper 16 feet high. E E (fig. 2) is a strong brass tube into which D D is firmly secured, and enters about $3\frac{1}{2}$ inches, but is removeable at pleasure. F F is a well-annealed hollow glass pillar, whose lower end is trumpet-shaped and ground flat; it rests upon the centre of the pedestal G G G, where it is firmly secured by eight bolts, f^1, f^1, &c., passing through a strong wooden collar, f^2, and the table of G. This pillar, with its high conductor, has resisted gales which were strong enough to blow down large trees in the neighbourhood; a certain degree of flexibility in the conductor diminishes the danger of the glass breaking considerably. A collar of thick leather is planted between F and the table, and some strips of leather are interposed between the excavated interior of the collar and the trumpet-shaped part of F (as seen in the plan annexed).

H (fig. 2) is a spherical ring fitted on the brass cap of F, and carrying I I I, which are three of four arms at right angles with each other. I (Plate XXXII. fig. 3) is a section of one of them, and of the ring H, to which it is firmly attached by means of a strong iron screw R, and the plug S. K is a ball fixed on the other end by means of a screw, L passing through its neck and a plug M. N is a cylindrical plug sliding accurately into K, and furnished with a screw n^1, which passes through a stopper O into a clamping-ball P. K and N are perforated to fit the sliding arm Q.

It is evident that by these means Q can be adjusted to any angle, with, and its ends to any required height, from the table of G G G; also that it can be very firmly secured without being galled.

K (fig. 2) is a little lamp for warming F F appropriately, k^1 its chimney of copper, closed above, passing through the table of G and entering, but not touching, F.

By this arrangement the lower part of F is generally warmed too much and the upper too little; but the pillar F being conical, &c., some zone always exists between the two ends, which is in the best state of temperature for electrical insulation*.

L is a pair of finely pointed platinum wires soldered to D.

M is Volta's small lantern, fitted to a ring m^1, from which it can easily be withdrawn when lowered by a person mounting the steps on the dome, m^2 its lamp; m^3 is a ring or tube sliding freely on D, and attached to M, &c.; m^4 is a silken line fastened to m^3, passing over a pulley (from which it cannot escape) at m^5, descending the interior of D and E, and winding upon a reel contained in the ball m^6, worked by a winch at m^7, for the purpose of raising and lowering M.

N is an inverted copper dish or parapluie, with a smooth ring on its edge, fitted by a collar and stays on E, and (of course) insulated by F: its least distance from a^1 is 3 inches.

One of the chief objects of this arrangement is to insulate the active parts of all the electrometers and the conductor itself by a common insulator, viz. the glass pillar F. The cord being contained in the tubular rod, cannot dissipate electricity from its fibres, and everything is well-rounded.

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* Mr. Read imagined (vide his 'Summary View,' &c. p. 105) "that if the insulation of his rod could be constantly kept in due temperature, it would always be electrified; but that that could not be done without the aid of common fire, which in so large an apparatus would be very difficult."

I believe we may safely affirm, that with the exception of a few hours of drizzling weather sometimes, and on occasions when our conductor has been touched, our rod has been every day, and *all* day, sensibly electrified since the moment of its erection (in June 1843).

ELECTROMETERS, &c.

The voltaic electrometers, which we used at first for the observations, were Volta's No. 1, or standard, O, fig. 2, and his second P, so modified that the straws suspended within square glass bottles with metallic bases, &c. were not suspended from the bottles themselves; but finding it difficult to avoid parallax and distortion by uneven glass, &c., I have endeavoured to improve these electrometers, and since the 16th of June we have used the following form, having first taken special pains to render the new instruments as nearly accordant with the old as possible (vide Experiments, *post*).

P (fig. 4) is a front view and O (fig. 5) a side view of a brass case (instead of a bottle) exactly 2 English inches wide internally, and furnished with plates of thin plate glass fixed by brass plates, &c. to its front and back: the back plate is ground to semi-transparency. The radius of the ivory scale *p* is equal to the length of the pair of straws Q (*i. e.*) 2 Paris inches, and the scale is graduated in half Paris lines. The scale of No. 1 counts single degrees, and each degree of No. 2 corresponds with five of No. 1.

The straws are suspended by hooks of fine copper wire inserted into their hollows and passing freely through holes in the flattened ends of the wire R, at the distance of half a line from each other. R passes through a glass tube S, covered with sealing-wax *by heating the tube* (not by spirit varnish). T is a cover cemented upon S, and, when the instrument is not in use, closing P. U is a ring to which R and S are attached, and V (fig. 5) is a knife-edged piece of steel riveted into a slit in U*.

The base (W X Y) of the instrument consists of three parts. W is a cylinder with a kind of flange, w^1, and is screwed firmly down upon a circular plate X. Y is a stout ring turning with friction about the smaller part of W, and X is secured firmly on the table of G by a bolt, screw-washer and nut Z, the bolt passing through a hole in G much larger than itself. The lower part, or plinth of P, has a shallow cavity beneath into which w^1 fits easily.

A is a tubular arm attached to Y, and carrying a steel wire B, which supports an eye-piece C; this can be adjusted and fixed at the required height from Y, in the same manner as Q (fig. 3). The distance of C from P, when in use, is *one English foot.*

R R (fig. 6) is a horizontal tubular arm fixed upon one of the vertical arms Q (fig. 3), and S S (fig. 6) are two little tubes with stoppers which slide into R and turn on their common axis; s^1 s^1 are notches cut down to the diameter of S S, and the horizontal parts of V (vide fig. 5) fit these notches.

Hence it is obvious, that when the adjustments have been made, an electrometer-case can be properly placed upon its base W, &c., and the straws Q, &c. suspended from S at exactly their proper height, without destroying the insulation of the warmed glass pillar (for it is necessary to handle P only), that U, &c. will then hang with sufficient freedom without liability to turn on their axis, and that C can be brought to exactly its proper position for noting the degrees on p^1, indicated by the divergence of Q. In like manner O can be removed and closed (as shown in the side view, fig. 5) without destroying the insulation, and finally, the whole of P X, &c. can be adjusted to make the straws accord with the zero point of p^1 (when unelectrified) and firmly fixed there †. I will not enter upon further particulars concerning the manner of using the sight-piece C in estimating fractions of degrees.

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* Cleverly suggested to me by Mr. Robert Murray.

† The Astronomer Royal has improved the manner of placing and displacing these electrometers at Greenwich.

$C^1 C^1 C^1$ is a strap of copper pressed under the washers at Z Z, and in good conducting contact with the strap of lead C (fig. 2)*.

The Henley electrometer (figs 7 and 8) is also constructed in conformity with Volta's improvements†.

The brass piece A is cylindrical below and flat above; on each of the smaller sides of the upper part is affixed a semicircular plate of ivory BB; through these the shanks of two little balls (CC) are screwed, which are drilled to receive fine steel pivots, carrying a little ball, into which the index (or pendulum) D is inserted: D terminates with a pith-ball E. The scale is divided into degrees of the circle: each degree should correspond with degrees of the Volta No. 2, and consequently with degrees of the No. 1 (or standard); every part is carefully rounded and smoothed.

It is supported by a piece of tube F passing through a clamping-ball and plug G, and that ball is affixed to one of the cross arms Q (vide fig. 3); the zero of the scale can be therefore accurately adjusted to coincide with the pendulum when unelectrified, and this can be made to rise in a plane cutting the axis of the conductor, &c. with the back of the instrument A turned towards the conductor, &c.; these are two essential conditions.

This electrometer has seldom been observed until the Volta No. 2 had risen beyond 90° (in terms of the first, *i.e.* 18 lines × 5); and since the uncertainty and difficulty of measuring the higher tensions increase in a rapid ratio with the increments of tension, owing to unavoidable and sometimes almost imperceptible "*spirtings*," and particularly to the falling of rain from the dish or funnel N (fig. 2), proportionably less confidence must, of course, be placed in our notations of such tensions by means of this instrument‡.

It also requires, according to Volta, De Luc, &c., small corrections for all degrees below the 15th and above the 35th, which have not been made in our Journal§.

A galvanometer by M. Gourjon, S (fig. 2), which Professor Wheatstone has placed on our table, will, I hope, prove the nucleus of a very valuable assemblage of new facts. In low intensities we have not yet been able to apply this instrument successfully, but in higher tensions the needles have been strongly affected.

The galvanometer in some improved form should perhaps supply that great desideratum in atmospheric electricity, a means of noting the dynamic effects which are perhaps coincident, if not identical, with the property discovered by Beccaria, and called by him "frequency," a property of great importance possibly considered in relation with the various opinions and theories which have been or still are entertained concerning the natural agency of atmospheric electricity, in vegetation, animal life, the magnetism of the earth, the aurora, &c.

Should we be enabled to prosecute these inquiries in the manner which the Professor has most ingeniously contemplated, or by means of a much more extensive collecting apparatus than the *single* lamp, &c., I hope that we shall do some good in this way.

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* The Cavalier' Amici has (on visiting the observatory), in a very kind and flattering manner, expressed his conviction that if Volta (his friend) could now see these improvements upon his electrometers and their application, he would be much pleased.

† Vide Opere del Volta, tom i. parte 2. p. 35 *et seq.*

‡ The oscillations of the index between the 30th and 35th degrees, sometimes during a heavy shower, plainly show that the electricity of the conductor is washed off, as it were, as fast as brought.

§ I have strong hopes that our principal use of all these electrometers will be that of comparing them with one torsion electrometer, alluded to in my former communication.

The discharger (fig. 9), also our "safety valve," is perhaps an improvement upon Lane's electrometer.

The length of the spark is measured by means of a long index R, which exhibits the distance of two balls, S and S', from each other on a multiplying scale T, S being attached to a rod V, which is raised and lowered by means of a glass lever W, forked piece X, &c.; V slides accurately through the base Y and the piece A. The bolt, &c. (Z), which is in intimate metallic connection with the safety conductor C, clamps the whole down to the table in the same manner as that in which the voltaic electrometers are fixed.

Each division of the scale represents an *exact* twentieth of an inch in the length of the spark. The actual cord of each division is about a tenth. The divisions are, of course, not perfectly equal to each other: they serve very well to estimate to fortieths, or less.

We observe a tolerably near approximation to coincidence between the lengths of sparks as measured by this instrument and the degrees of tension exhibited by the Henley.

A Bennet's gold-leaf electroscope, in form a little differing from fig. 10, has been sometimes used for discovering the length of time which has elapsed between the alternations in *kind* of electricity during rain, &c., and *very rarely* for ascertaining whether our conductor was charged or not on other occasions*.

A wire A, terminating below in a pair of forceps, carrying the paper by which the leaves are suspended (in Bennet's manner nearly), passes through a glass stopper B, which is ground into a long-necked bottle C, with a metallic base D, and a strip of brass (E) is bent and screwed to the inside of D. The neck of C is well-covered with sealing-wax by heating both inside and out†.

If required, this instrument can be suspended from an arm, as R (fig. 6), and a chain hooked on a ring in its base, but here we depart from the principle of uniform insulation, and therefore seldom use a Bennet's electroscope in this manner, but merely touch the conductor with it.

DISTINGUISHER.

The distinguisher, which we have found most convenient for ascertaining the kind of electricity possessed by the conductor, &c. at any given time, and in all tensions except the very lowest, is of the sort represented by fig. 11.

A is a wire connected with a brass tube which forms the interior coating of a very thin glass tube C. B is an exterior coating of the same kind, and these two coatings are at about three-fourths of an inch distant from each extremity of this little Leyden jar. The intervals D C and B C are coated with melted sealing-wax inside and out. A thus prepared is inserted through a stopper,

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* In measuring low intensities, and particularly small quantities of electricity, the mode of insulation called 'Singer's' is sometimes very objectionable, for this reason; the wire (as A) carrying the gold leaves, or other pendulums, becomes partly the interior coating of a charged glass cylinder, and part of the cap of the instrument becomes the exterior coating; the contact of the electrometer with the body whose electric tension is to be ascertained, lowers consequently, and sometimes materially, the tension of that body itself. The charge received by such an instrument is retained well, principally by reason of these associated metallic coatings, &c., and it seems to lose electricity more slowly than it does, because it has more to lose than it seems to have.

† The principal conductor, its appendages and instruments in the electrical observatory, hitherto described, were *chiefly* executed by Mr. Newman of Regent Street, and do him very great credit.

fitted to a bottle D with metallic base, and is provided with a pair of gold leaves rather too short to reach the sides of the bottle, the neck of which, both inside and out, is also coated with sealing-wax as usual.

This distinguisher is charged every morning negatively, and never fails to retain a good charge for the twenty-four hours. It is conveniently placed upon a bracket, a few feet distant from the conductor, &c., to which when used it is approached by hand, to some distance proportionate to the height of the charge. If the charge is positive, the leaves of course collapse more or less, but open again when withdrawn; and if it be negative, the divergence increases, &c.

Perhaps this mode of distinguishing is preferable to Beccaria's method of the star and brush, or even to that of the dry electric column, &c., for the operation can be performed without the least danger of lowering the tension of the conductor or injuring the gold leaves, let the height of the charge be what it may*.

ELECTROGRAPH.

An electrograph (fig. 12), of the kind proposed first I believe by Landriani and afterward by Bennet and Gersdof (but of which no particulars seem to have been published before 1823†), has also been used, but not extensively, for reasons which will be hereafter explained.

A is a plate of tin coated with a thin layer of shell-lac, &c., as carefully as possible deprived of air-bubbles, flaws and inequalities. B is a case containing a time-piece moved by the weight C. D is part of a triangular little frame fitted to the hour arbour of the time-piece and supporting A. E F is a bent lever whose fulcrum is at e', below its centre of gravity: the part F is of coated glass. G is a ball through a groove of which E F passes, and G is supported by a cross arm of the conductor.

When this instrument was used, the end E was allowed to rest with very little pressure upon A, which being carried round by the clock became electrified in the line and neighbourhood of its contact with E to an intensity proportional to the charge of the conductor. After having been allowed to perform a full revolution, or any given part of one, under these circumstances, A was removed from D and well-powdered with chalk, projected upon it from a lump rubbed upon a hard brush. The powder, of course, as in Lichtenbourg's figures, adhered almost exclusively to the parts which had been more or less electrified by and in the neighbourhood of E; and a figure was produced, of which a calotypic image, kindly executed for me by Mr. Collen, by means of his camera obscura, &c., is preserved as a specimen. Many such images could be produced in a few fine hours from A, and thus a sort of pictorial register of atmospheric electricity (of serene weather at least) be circulated amongst meteorologists, care being taken of course to note the time of putting on and taking off the resinous plate.

That figure was made contemporaneously with hourly observations of the voltaic electrometers. The plate, after the powdering, was placed upon a circular paper, divided as the hours of a dial, and the intensities (as 35°, 25°, 16°, &c.) were marked against the appropriate hour, by which it may be seen that, excepting at the hour of six, the breadth of the line or figure corresponds pretty nearly with those intensities.

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* Indeed I do not know whether some some such contrivance might not be applied to *measure* as well as distinguish the charge of the rod; particularly if the insulation of the gold leaves were preserved by means of chloride of calcium in a manner hereafter to be spoken of, the distance from the rod being made the measure of tension.

† Vide Descriptions of an Electric Telegraph, &c., p. 47.

Mr. Collen's photographic impression of a one-hour plate, which was fixed upon the minute arbour of the clock, is also preserved*.

A LEYDEN JAR, of about 40 inches coating, has been sometimes used for receiving the charges from the rod, and the number of discharges up to the maximum tension of the rod in a given time has furnished a better estimate (in very high tensions and quantities) of frequency, than we at present otherwise arrive at perhaps.

A PAIR OF BELLS has been sometimes applied to the conductor in the usual way, but they are too small to give us due notice below of high charges.

AN ARGAND LAMP is burned at about 3 feet from the conductor in the evening, for lighting the electrometers, &c., and a little chimney placed above it, and opening outside the dome to prevent hot air and vapour from approaching the conductor, or anything connected therewith.

A SMALL JOYCE'S STOVE, containing a little burning charcoal at night, is generally suspended in the dome for keeping everything dry.

Great care is requisite, and diligently observed by Mr. Galloway, to guard as much as possible the whole apparatus from dust. He uses occasionally *soft* camels'-hair brushes.

I believe that every article which has been used, more or less constantly, for the *electric* observations of the tables, has now been shortly described.

I placed A CONDENSER in the room, but we have not used it. I think that Volta's objections to the employment of such instruments in comparative experiments are founded in sound reason and experience.

BAROMETERS.

The mountain barometer, lent by Colonel Sabine until we can afford the expense of a standard instrument, has been used since the commencement of the observations here; it is by Newman; the graduated scale is divided to 0·05 of an inch; the vernier subdivides the scale divisions to 0·05, and is moved by a slow screw.

The particulars given, for corrections, are as follows:—

Capacity	1·55
Neutral point	29·764
Capillary action	+0·043
Temperature	55°

It is freely suspended by a ring in the mural quadrant-room B (fig. 1), near the north window. It has been compared with the barometer of the Royal Society, and the comparison is recorded there.

The observations are set down without corrections of any kind.

A centigrade barometer hangs freely in the dome, but we use it for casual observations merely, and seldom.

THERMOMETERS.

The thermometer which we call our *standard*, by Newman, is mercurial, and divided to 0·5; it has not been compared with others. It is fixed at the outside of the north window of the apartment B (fig. 1).

The maximum thermometer is mercurial; it is made by Newman, is divided to 0·1, and the index is of blue steel. It is placed outside the north window of the room B (fig. 1), near the standard thermometer.

The minimum spirit thermometer, by Newman, is divided to 0·1, and the index is of black glass; its position is nearly the same as that of the maximum thermometer, *i.e.* on the opposite side of the same window.

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* This kind of graphic exhibition is perhaps more pleasing but less useful than other modes of registration which we hope to accomplish. The tædium and difficulties of bringing the resinous coating to a uniformly fit state for receiving the electrical drawing are not inconsiderable.

HYGROMETERS.

The wet-bulb thermometer of *Mason's hygrometer* is mercurial: its scale is divided to 0·1. The difference between this wet thermometer and the dry, as set down in our observations, is derived from a comparison of it with our standard thermometer. This hygrometer has been placed outside of the same window, near the standard thermometer, about an hour before every observation.

The thermometer inclosed in one of the bulbs of the *Daniell hygrometer* is also mercurial, and its scale divided into 0·1. The difference between the dew-point and the dry thermometer, as set down in our tables, is also derived from a comparison of this thermometer with our standard thermometer. We found that the exterior thermometer varied from the standard sometimes $1\frac{1}{2}°$. This excellent hygrometer is used at the same open window.

The Saussure hygrometer is of the six-haired kind, made by Richer of Paris. A system of levers is employed, by means of which the effect upon the index is the mean result of all the expansions and contractions of the hairs. It has the advantage of great strength, at least, but is slow and is much less to be depended upon than the Daniell. Before the observation it is exposed for about an hour outside the same north window of the room B (fig. 1).

RAIN AND VAPOUR GAUGE.

This is, I believe, a new instrument. It indicates a mean result arising from the quantity of water which may have fallen between any two given periods, minus the quantity of vapour which has risen in the same time (and, of course, *vice versâ*) on and from a circular plane of one foot diameter.

A A (fig. 16), Plate XXXI. is a cylindrical vessel of zinc whose internal diameter is one foot.

B is another cylindrical vessel attached to A, and communicating by a little pipe *b* with it. C (vide dotted lines) is a glass vessel standing in B, and having a small perforation near its foot. D D is a circular plate of brass firmly screwed to a cap C, and $d^1 d^1$ is a copper plate attached to the cap of C also. E and F are cocks fixed upon D at a distance of about three-quarters of an inch from each other. G is a pulley upon an arbour, which runs in centres opposite to each other in the supports E and F; the centres are jewelled, and the carefully turned pivots of the arbour are of platinum. H is an index carried by G, and I I I is the scale secured upon F. K is a silken thread passing round a groove in G, descending through a hole in D, and suspending a light copper covered dish L. M is another silken thread passing in the contrary direction round another groove in G, and suspending a weight N, which is somewhat lighter. Lastly, P is a glass shade placed upon D D.

This arrangement embraces a manifest application of the principle of the wheel barometer. If a quantity of water is poured into A, exactly sufficient to bring the index H to a given point, and if afterwards any addition to that quantity of water should be made by rain, the index will point out the increase upon the multiplying scale I; or if any diminution of that quantity should be occasioned by evaporation, the loss will also be pointed out by the motion of the index in the contrary direction.

We have always therefore brought the index to zero by addition to or subtraction from the water in A at *sun-set*, and have observed at that hour the mean results of deposition and evaporation for the preceding twenty-four hours. A little reservoir is placed near it with a pipe and cock for supplying water conveniently. This instrument is fixed upon a stand at about two feet above the leaden roof (fig. 1), but would be much more properly situated if the cylinders A and B were sunk into the neighbouring earth, and I hope that we may at some future time be allowed a very little space for this purpose*.

The use of the plate $d^1 d^1$ and of the glass shade P, is to exclude rain from B, and for protection.

The platinum pivots and jewelled holes effectually prevent the inconveniences of oxidation, &c., and the instrument performs its office with great delicacy and fidelity.

If it were required to be used occasionally as a *rain-gauge* only, a funnel might be fitted upon A; if for a vapour-gauge only, the whole might be protected from rain by a sort of roof or covering placed at some feet above it.

Vane.

Our wind-vane, fig. 17, Plate XXXI., is rather more convenient and accurate than a common weather-cock. A is a small brass tube at whose upper end is fixed a hard steel cap with a conical cavity, which turns upon the hard steel point of a little rod screwed into a brass cap B, and B is fixed upon a pole C; S N is a very light tin hoop, having the points of the compass painted upon it, and attached by arms to A, therefore it is carried round by A; D is an index formed of a bent wire attached to B; E is the vane fixed to A and counterpoised by F.

This instrument is so placed, that the point of D, and whatever letter painted on S N stands above it, are always in the plane of the observer's eye viewing it through the window B of fig. 2.

Anemometers.

Lind's anemometer, as usually made by Watkins and Hill, has been consulted, but is so very much less sensible than is necessary, (for the lightest zephyr is as important, at least, as the stiffest breeze to electrical meteorology,) that we were induced to try

M. Guyot's, but with no better success; I was therefore driven to the necessity of inventing a somewhat rude but far more efficient expedient, which we call our

Balance anemometer.—This turns with a weight of ten grains (or less), and can be made to carry as many pounds (or more). A (fig. 15) is a light feather-edged deal board exactly 1 foot square; B is a cross formed by two pieces of wood and carrying A at b^1; a leaden counterpoise C, at b^2; a little arm, hook and scale-dish D, at b^3; and a counterpoise thereto at b^4. B is supported by nicely-turned brass pivots running in two little pieces of glass tube attached to the supports E E, which are firmly secured upon a large base F; G is a kind of sentry-box†, with a projecting roof for protecting D B, &c. from the wind; H is a little vane, and I a pin thrust through E E and the arm b^2, when the instrument is not in use. The whole has a coat of hard white paint.

The application of this mechanism is obvious. When the flat front of A is placed at right angles with the direction of the wind (Z), which can be done with tolerable accuracy by the help of H, D rises with weights placed in the dish proportional to the force of the wind acting upon the square foot A. We measure by grains.

Great improvements as to making it self-adjustable to the direction of the

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* It might then, perhaps, indicate more accurately a certain relation to the amount in excess in evaporation, &c. from an aqueous surface on the earth. It should perhaps be made to float upon such a surface in a little boat or buoy.

† The invention of Sergeant Galloway, who made nearly the whole instrument.

wind observable out of doors, without going out, &c. will occur to everybody*.

It has been placed upon any part of the balustrade (fig. 1), which may have been freely exposed to the wind at the time of observation.

II. *Explanation and Remarks concerning the Journal, &c.*

In column A the letters "S R" and "S S" designate sunrise and sunset.

In column B, "P" means positive charge, and "N" negative charge of the conductor.

In column C, the four regular electrical observations of the day, viz. at sunrise, at 9 A.M., at 3 P.M., and at sunset, are put down.

In columns D, E, F are contained the designations of the electrometers by which each observation was made. V stands for Volta's, H for Henley's, and D for the discharger. The figures preceding D are fractions, &c. of an inch.

In column E is contained the minimum and maximum charges derived from observations made, *generally*, every hour between sunrise and meridian. N.B. The early morning charges before sunrise (usually low) are not taken into account.

In column G is contained the minimum and maximum charges derived from, *generally*, hourly observations between meridian and about 10 P.M., the nightly charges after 10 not being taken into account.

In column I is contained, *sometimes*, a few very rough intimations of the rate at which the charge of the conductor rises to a maximum after it has been touched.

Column K was intended for the deviations of the electro-magnetic needle, but the galvanometer is not yet fitted for such notations regularly.

Column L should contain notices of the side of the card to which the needle moves.

In column M, a few indications of the number of storms occurring in the course of a day are *sometimes* set down.

In column N is pointed out (by the letter S) such days as generally occur when the positive charge rises after sunrise, falls early in the afternoon, and rises again in the evening, accompanied by what is commonly understood by the term "fine weather;" but there are exceptions to this (rather vague) definition which I believe require some habit and an acquaintance with the observations of Monier, and others, particularly Beccaria, to appreciate.

Columns O, P, Q require no explanation. The dry thermometer is our standard.

In column R the observations are not copied after the 31st Dec. 1843. They were too anomalous to be of any possible use.

In columns S and T many anomalies are to be found.

In column U is contained (under E) the amount of evaporation in excess of rain from *sunset to sunset*; the degrees measure hundredths of an inch in the height of the water contained in A and B, fig. 16, Plate XXXI.

In column V is contained (under R) the excess of rain above evaporation for the same period.

In the column W, the direction of the wind, as shown by the vane on the dome, is marked.

In column X, the maximum pressure of the wind from sunrise to sunset is noted from the 1st of August 1843 to the 9th of February 1844. After this

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* Dr. Robinson of Armagh suggests the employment of a chain of links, &c. winding upon a reel, for saving time and trouble in placing the weights in the dish.

date the pressure is set down at the hours of 9 and 15. [The frequent recurrence of the 0 proves the great insensibility of the Lind anemometer.]

In column Y the forces of wind acting upon the balance-anemometer are in grain weights.

In column Z the changes of the moon are placed opposite to the nearest hours (which had been previously written for other purposes) to those at which they occurred.

Under the title "General Remarks and Occasional Observations," Mr. Galloway's nomenclature of atmospheric appearances is pretty closely adhered to. It will not always be found strictly logical and consistent, but I could not improve it without risk of damaging the general sense. When we came to the 7th of Nov. 1843, it seemed better to copy his notes from the book, in which they were originally set down, than to take his general accounts compiled from that book and from memory the next morning.

A few words should be here devoted to the observer, &c.

The observations of all kinds were made almost exclusively by Mr. Galloway, whose notes were first written, some on papers prepared for the purpose, and kept in the quadrant-room below; others in the above-mentioned book, kept in the electrical observatory, and more frequently inspected.

I am quite satisfied that he has executed his task better than could have been expected; but must add *emphatically*, that had our habits and qualifications been always adequate to the attainment of extreme accuracy, our instruments and other means would have been far from being so.

In short, although the electrical part of the journal (even under these circumstances) is more complete and accurate than any such hitherto recorded, yet this year's work (*i.e.* from the 1st of August 1843 to the 31st of July 1844) must, in spite of all our efforts, be considered upon the whole, and principally, as educational and experimental.

The *form* of the Journal is copied as closely as circumstances of space, &c. would permit, from the Astronomer Royal's admirable Tables of "*Ordinary Meteorological Observations*" at the Greenwich Royal Observatory.

Specimen of Electro-Meteorological Observations,

TIME.	ELECTRICITY.												BAROM. PRESS.	TEMPERATURE.		HUMIDITY.		
Day and Hour. Chronometer uncorrected.	Kind.	Periodical Observations.		Morning Min. & Maximum.		Afternoon Min. & Maximum.		Frequency.	Galvanometer.		Storms.	Serene Days.	Barometer uncorrected.	Maximum and Minimum Thermometer.	Dry Therm.	Wet Therm. below Dry.	Dew-Point below Dry.	Saussure's Hygrometer.
1844. d h m		°		°		°			°				in.	°	°	°	°	°
July 28. SR.	P.	17	V.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
„ 9 0	P.	55	V.	...	...	...	...	...	...	...	...	...	30·306	76 52	74·25	...	19·75	63
„ 15 0	P.	12	V.	...	...	...	...	...	...	...	...	...	30·224	...	81·75	...	30·75	49·5
„ SS.	P.	22·5	V.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
„ SR.	P.	...	...	17	V.													
„ 9 0	P.	...	...	55	V.													
„ 16 0	P.	...	...	...	...	9	V.											
„ SS.	P.	...	...	...	...	22·5	V.	...	...	...	...	S.						
July 29. SR.	P.	7	V.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
„ 9 0	P.	7	V.	...	...	...	...	...	...	...	...	...	30·04	82 58	62·5	...	15	63·5
„ 15 0	P.	9	V.	...	...	...	...	...	...	...	...	...	30·02	...	69	...	28·5	53
„ SS.	P.	15	V.	...	...	...	...	...	...	...	...	S.	...	...	...	...	...	...
„ 5 0	P.	...	...	4	V.													
„ 12 0	P.	...	...	17	V.													
„ 14 0	P.	...	...	...	...	5·5	V.	...	...	...	...	...	...	...	...	...	...	...
„ 22 0	P.	...	...	...	...	47·5	V.											
July 30. SR.	P.	19	V.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
„ 90 0	P.	32·5	V.	...	...	...	...	...	...	...	...	...	29·866	70 49	62	...	19·5	66·5
„ 15 0	...	...	...	...	...	...	...	...	...	...	...	...	29·65	...	66·5	...	18·5	85·5
„ SS.	P.	12	V.	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...
„ 10 0	P.	...	...	15	V.													
„ 8 0	P.	...	...	45	V.													
„ 16 0	P.	...	...	...	...	5	V.											
„ 15 25	N.	...	...	...	...	3	H.											
July 31. SR.	P.	5	V.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
„ 9 0	P.	25	V.	...	...	...	...	...	...	...	...	...	29·628	67 57	65·5	...	10	79·5
„ 15 0	P.	9·5	V.	...	...	...	...	...	...	...	...	...	29·74	...	68	...	20	64
„ SS.	P.	40	V.	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...
„ SR.	P.	...	...	5	V.													
„ 8 0	P.	...	...	27·5	V.													
„ 15 0	P.	...	...	...	...	9·5	V.											
„ 15 40	N.	...	...	...	...	40	H.											
„ „ „	„	...	...	...	...	$\frac{4}{10}$	D.											
A	B	C	D	E	F	G	H	I	K	L	M	N	O	P	Q	R	S	T

at the Kew Observatory, in the Year 1844.

RAIN AND EVAP.		WIND.			MOON.	GENERAL REMARKS AND OCCASIONAL OBSERVATIONS.
Mean of Rain & Vapour-Gauge.		Direction. by Vane.	Pressure. by Lind's Anemom.	by Balance Anemom.	Phases.	
E.	R.		°	grs.		
...	...	N.N.W.	...	......	....	July 28. At SR. fine, but cloudy.—From 5 to 16 fine, cloudy, with sunshine.—At 17 and 18 fine, but cloudy.—At 19 dull and cloudy.—At SS. light rain.—At 21 and 22 dull and cloudy.
...	...	N.N.W.	0	500		
...	...	S.W.	0	1500		
26	...	S.W.				
...	...	W.S.W.	...	......	....	July 29. At SR. dull and cloudy.—At 5 light rain.—At 6 and 7 dull and cloudy.—At 8 fine, but cloudy.—From 9 to 19 fine, but cloudy, with sunshine.—At SS. fine, but cloudy.—At 21 and 21·45 clear and starlight.
...	...	N.	1	2500		
...	...	N.W.	2	4500		
21	...	N.N.W.				
...	...	....	...	......	Full.	
...	...	S.W.	...	......	....	July 30. From SR. to 8 fine, but cloudy.—At 9 fine, but cloudy, with sunshine.—At 10 heavy drops of rain.—At 11 and 12 dull and cloudy.—At 13 fine, but cloudy.—At 14 dull and cloudy.—At 16 and 17 fine, but cloudy, with sunshine.—At 18 heavy rain.—At 19 fine, but cloudy.—At SS. and 21 dull and cloudy. Between the observations of 15 and 16 a storm occurred. (Vide Storm papers, No. 4.)
...	...	S.	3	3000		
...	...	S.S.W.	3	9000		
...	6	W.S.W.				
...	...	W.S.W.	...	......	....	July 31. At SR. and 5 fine, but cloudy.—At 6 fine, but cloudy, with sunshine.—At 7 fine, but cloudy.—At 8 and 9 fine, but cloudy, with sunshine.—At 10 fine, but cloudy.—At 11 light rain.—At 12, 13 and 14 fine, but cloudy.—At 15 light rain.—At 16 fine, but cloudy, with sunshine.—At 17 fine, but cloudy.—At 18 and 19 fine, but cloudy, with sunshine.—At SS. and 21 fine, but cloudy. Between the observations of 16 and 17 a storm occurred. (Vide Storm papers, No. 5.)
...	...	W.S.W.	5	8500		
...	...	W.N.W.	4·5	5000		
12	...	W.				
U	V	W	X	Y	Z	

Specimens of Storm Papers.

1844. No. 1.

Time.	Electricity.			Incidents and Remarks.	Wind.
July 1.					
h m		°			
17 30	N.	60	H.	Dull and cloudy.	
17 40	...	70	H.	Rain beginning .	W.
......	...	$\frac{11}{20}$	D.		
17 45	N.	5	H.	Rain increasing.	
17 50	N.	20	H.	Rain heavy	W.
17 52	P.	40	H.	Id.	
17 53	N.	20	H.	Storm, Squalls, Rain.	
17 53	N.	30	H.	Very heavy rain, Oscillations.	
17 54	N.	30	H.	Sudden collapse.	
17 55	N.	15	H.	Heavy rain, Collapse	W.
17 56	P.	60	H.	Id. Flash.........	W.
18 0	N.	35	H.	Id. Sparks frequent	N.W.
......	...	$\frac{3}{10}$	D.	Id.	N.W.
18 1	N.	40	H.	Id.	N.W.
......	...	$\frac{3}{10}$	D.	Id.	
18 4	N.	50	H.	Id.	N.W.
......	...	$\frac{7}{20}$	D.	Id.	
18 5	N.	60	H.	Id.	N.W.
......	...	$\frac{4}{10}$	D.	Id.	
18 7	*q.*	*q.*	...	Id. Current of fire	N.W.
18 12	N.	*q.*	...	Id. 5 charges of jar in 40″......	N.W.
18 16	N.	40	H.	Heavy rain	N.W.
18 24	P.	50	H.	Id. Flash, Collapse...........	N.
18 25	N.	30	H.	Heavy rain	N.
18 26	P.	25	H.	Id.	N.
18 35	N.	20	H.	Id.	N.
18 37	N.	40	H.	Id.	E.
18 47	N.	45	H.	Id.	E.
18 55	N.	40	H.	Id. 8 charges per minute.........	E.N.E.
......	...	$\frac{3}{10}$	D.	....	E.
19 0	P.	5	H.	Rain lighter......	E.
19 5	P.	25	H.	Id.	S.E.
19 21	N.	20	H.	Rain heavier ...	S.E.
19 28	N.	35	H.	Rain lighter......	S.E.
19 34	N.	37	H.	Rain nearly ceased	S.E.
19 50	N.	5	H.	Rain ceased......	S.E.

1844. No. 3.

Time.	Electricity.			Incidents and Remarks.	Wind.
July 19.					
h m		°			
15 20	N.	60	H.	Flash, Thunder near	N.W.
15 21	P.	65	H.	Id.......... Id....	W.N.W.
15 22	N.	40	H.	Large hail stones	W.N.W.
15 23	N.	60	H.	Hail heavy.	Id.
15 30	N.	50	H.	Hail very heavy .	Id.
15 35	N.	55	H.	Flash, Hail still heavy.	Id.
15 37	N.	40	H.	Flash, id. id...	Id.
15 40	N.	50	H.	Rain not so heavy	Id.
15 45	N.	50	H.	Id. heavier......	Id.
15 49	P.	50	H.	Id. lighter.......	Id.
15 55	P.	45	H.	Id. little.........	Id.
16 0	P.	45	H.	Id. much lighter.	Id.
16 47	P.	10	H.	Fine but cloudy with sunshine.	W.S.W.

Sometimes during this storm when flashes occurred, streams of fire passed between the balls of the discharger, lasting a second or two. The noise resembled that of the violent rending of paper, but was much louder.

No. 4.

Time.	Electricity.			Incidents and Remarks.	Wind.
July 30.					
15 25	N.	$\frac{3}{10}$	D.	Heavy rain.	S.W.
15 35	N.	30	H.	Id.	Id.
15 36	N.	6	H.	Id.	Id.
15 39	N.	90	H.	Id.	Id.
15 40	P.	6	H.	Id.	Id.
15 41	N.	10	H.	Id.	Id.
15 46	P.	4	H.	Id.	Id.
15 47	N.	10	H.	Id.	Id.
15 49	N.	20	H.	Id.	Id.
15 51	P.	4	H.	Rain lighter......	Id.
15 56	P.	10	H.	Fine with sunshine.	Id.

III. *Experiments made at the Kew Observatory in* 1843 *and* 1844.

I sincerely hope that we have not wasted *much* of the sum granted for the support of this establishment at the last meeting of the Association, in endeavouring to prosecute what we conceive to be one of its chief objects. Some of the experiments (here selected from a large collection) were absolutely necessary (to authenticity), others yet imperfect may possibly become complete and useful, as they may be further pursued, and some are or may become completely useless. None of them are comprised in the many trials which were made previously and more or less subservient to the construction of the principal conductor and its appendages, or to the several improvements already described of other instruments employed in the observations. They may perhaps, in conjunction with the Journal, &c., serve at least to show that sufficient precautions have not hitherto been taken for conducting electro-atmospheric observations to even approximative *comparability*, and may possibly tend to induce far more able inquirers to favour us with wholesome advice and assistance. In fact this result has already been in some measure obtained in the instance of our zealous and able friend Dr. Robinson, and several very eminent professors.

1. COMPARISON OF VOLTAIC ELECTROMETERS.

Two glass pillars (called *a* and *b*), similar to F (fig. 2), were mounted, with their collars, &c., upon a broad wooden shelf in the recess of the southern window of the southern room D (fig. 1); each was provided with its warming-lamp, chimney, &c., and an arm projecting horizontally from the cap, which arms supported the pairs of straws, &c. of the voltaic electrometers to be compared (as in fig. 4), and the caps were placed in good conducting communication by a wire. The electrometers, &c. were charged (by an electrophorus) as highly as they could be without causing the straws to strike the sides, and their divergences were not noted down until the straws had somewhat collapsed. The electrometers A and C are of Volta's first or standard kind; B and D of his second kind.

Time.	Insulator *a*. Electrometer A.	Insulator *b*. Electrometer C.
Feb. 1.	20°	20°
	15	14·5
	10	10
	5·25	5
	Electrometer B.	Electrometer D.
Feb. 3.	90	90
	80	80
	67·5	70
	47·5	50
	27·5	30
	17·5	20
	Electrometer A.	Electrometer C.
Feb. 6. $13^h 48^m$	20	20
	16·5	16
	10·5	10

This experiment (or set of experiments) suffices to show, that our ordinary voltaic electrometers possess a tolerable approximation to comparability. [It is difficult to estimate a much smaller quantity than 2°·5 of the electrometers B and D, or half a degree of A and B.]

2. COMPARATIVE INSULATING POWERS OF TWO INSULATORS.

All things remaining as in experiment 1, the electrometers were charged, and after time had been given them to fall a little, the caps of the insulators, *a* and *b*, were contemporaneously deprived of conducting communication by withdrawing the uniting wire by means of a glass handle attached to its central part.

	Insulator *a*. Electrometer B.	Insulator *b*. Electrometer D.
Feb. 3.	67·5°	70°
	47·5	50
	27·5	30
	New charge.	
	77·5	80
	57·5	60
	37·5	40

The window was now opened and a board was fitted into the frame (of the sash), having two apertures of about 5 inches diameter, situated a little higher than the caps.

	Time.	Insulator *a*. Electrometer A.	Insulator *b*. Electrometer C.
Feb. 6.	$14^{h}\,38^{m}$	20°	20°
		14·25	14
		9·5	6

The apertures of the window-board were diminished to $2\frac{1}{2}$ inches diameter, and the lamp of the insulator *b* raised a little. A double wick was used in it.

	Time.	Insulator *a*. Electrometer A.	Insulator *b*. Electrometer C.
Feb. 9.	$14^{h}\,15^{m}$	20·5°	20°
		14	14
		5·5	5
		New charge.	
		20	20
		5·5	5·5

The board was removed and the window closed. Both the lamps were used with double wicks and their chimneys attached to a lower board or shelf (as in fig. 3), in order to prevent more effectually any hot air with steam (arising from the combustion) from reaching the caps, &c.

	Time.	Insulator *a*. Electrometer A.	Insulator *b*. Electrometer C.
Feb. 14.	$14^{h}\,1^{m}$	19°	19°
		10	11
		6	5

The window was again opened and the board with the smaller holes used.

	Time.	Insulator *a*. Electrometer A.	Insulator *b*. Electrometer C.
Feb. 15.	$10^{h}\,15^{m}$	20°	20°
		6	5
		Electrometer B.	Electrometer D.
		80	80
		60	60
		25	25
		10	10

Here we have also a very fair approach to comparability.

3. Comparison of three Insulators.

The insulators *a* and *b* remaining as in experiment 2, and the window being closed, a third insulator (*c*) was attached by its collar, &c. (as usual) to a round table placed near to the others, with its chimney-lamp, &c., but no *lower shelf* was used. The electrometer E used with C had been found to accord very nearly with A and C. A fire burned in the stove of the room.

	Time.	Insulator *a*. Electrometer A.	Insulator *b*. Electrometer C.	Insulator *c*. Electrometer E.
Feb. 24.	$9^{h}\,20^{m}$	20°	20°	20°
		5	4	4
			New charge.	
		20	20	20
		6	5	4

The insulator *c*, with its table, &c. removed into the north room, without any fire in the stove.

	Time.	Insul. *a*. Elect. A.	Insul. *b*. Elect. C.	Insul. *c*. Elect. E.	Daniell's Hygrom. in S. Room.	Daniell's Hygrom. in N. Room.
	h m	°	°	°	°	°
Feb. 25.	14 5	20 3	20 1·5	20 0	14	8
„ 26.	9 15	20 4	20 2·5	20 2	13	12
„ 26.	13 2	20 6·5	20 4	20 4·5	14	12
Mar. 7.	14 17	20 6·5	20 7	20 4	30	22
„ 8.	11 43	20 4	20 2	20 4	26	21
„ 10.	9 20	20 6·5	20 4·5	20 3·5	16	9
„ 14.	14 45	20 5	20 3·5	20 5	19	12

It appears from these observations that very little difference arises in the insulating powers of our warmed glass pillars, from the circumstance of their being placed in an atmosphere a little more or less humid and cold.

4. Comparison of two united with two single Insulators.

In the *united* state of the insulators *a* and *b*, in these experiments everything was disposed as in experiment 1.

In their *single* state the uniting wire was withdrawn in the manner stated in experiment 2.

	Time.	Insul. *a*. Elect. A.	Insul. *b*. Elect. C.	Daniell's Hygrom.	Mean Loss in Time.		
	h m	°	°	°	°	h m	
Aug. 31.	11 21	20	20	23	......	......	united.
	13 22	3·5	3·5	...	......	......	
					16·5	2 0	
	13 35	20	......	...	......	......	single.
	15 35	3·5	......	...	......	......	
					16·5	2 0	
Sept. 11.	14 5	20	20	...	......	......	united.
	15 25	3·5	3·5	...	......	......	
	14 30	......	......	24	16·5	1 20	
	15 29	20	20	...	......	......	single.
	16 52	4	3·5	...	......	......	
	15 33	......	......	26	16·25	1 23	
	10 6	20	20	...	......	......	united.
	11 3	3·5	3·5	...	......	......	
	10 25	......	......	18	16·5	1 24	
	11 34	20	20	...	......	......	single.
	13 25	4	3·5	...	......	......	
	11 37	......	......	21	16·25	1 51	
	13 30	20	20	...	......	......	single.
	15 17	5·5	3·5	...	......	......	
	13 34	......	......	22	15·5	1 37	
	15 13	20	20	...	......	......	united.
	17 44	4	3·5	...	......	......	
	15 45	......	......	24	16·25	2 31	

From this 4th set of experiments, it would seem that two warmed insulators retained the charge as well as one; and that therefore in the same situation each insulated "*perfectly*," using this expression in Coulomb's sense. But circumstances may arise in applying this kind of test to render the conclusion defective. The *two* caps, &c. (having greater capacity and quantity) should retain the charge better than one, &c.

It is evident that certain mysterious conditions of the ambient air interfere sometimes with our operations of this nature, and (as Sir David Brewster justly remarks) experiments should be undertaken to find them out*.

5. EXPERIMENTS ON INSULATION BY MEANS OF CHLORIDE OF CALCIUM.

The object of these experiments was to ascertain how far it might be practicable to construct electrometers which should lose the lower and more usual charges, received from the principal conductor, at given periods, in some near approximation to constant rates, yet not lower the tension of the conductor materially, on contact with it. For it is necessary to a more exact prosecution of our inquiries, that the true electrical state of the conductor, as regards both tension and kind, should be known at certain intervals of the night more accurately than it can be by means of the resinous electrograph described at p. 126.

In order to procure the greatest possible constancy of loss, it was (obviously) very desirable to obtain the greatest possible retention, and for this purpose non-conducting or semi-conducting laminæ, coated on both faces with good (or better) conductors, naturally presented themselves as being capable of retaining low charges for very great lengths of time. But these require, proportionably, much larger *doses* of electricity to produce equal effects on *tension* electrometers than simple conductors (not thus "compensated"), and would, consequently, lower the tension of the principal conductor *materially* at the time of receiving their charge from it.

In endeavouring to discover the best means of retaining a *small quantity* of tension ("frictional") (*q*) electricity a long time, I first employed receivers, air-tight and of various dimensions, containing vertical rods of glass (cut from the same piece) about 3½ inches long and a ¼ of an inch in diameter. They carried horizontal brass wires from which were suspended pairs of *natural* voltaic straws (as in fig. 4), and were coated with the best *engraver's* hard sealing-wax, applied by heating the glass sufficiently to melt the wax (not by *spirit* varnish, which is far less effective). The receivers also contained each 2 or 3 ounces of chloride of calcium (below). The electrometers were charged (by an electrophorus) after lifting the receiver up from the flat glass plate on which they were placed (with a little oil in the joint).

These experiments proved that an electrometer originally charged to about one inch divergence of Volta's No. 1, or standard pair, would retain for the space of from 114 to 124 hours (by the above means), some remainder of its charge†; also that small receivers were better than large, &c.

But it soon appeared that after the straws had been for two or three days exposed to the action of the chloride, *they* became insulating in a very inconvenient degree, for when the wires supporting them were touched (continu-

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* Vide Encyclopædia Britannica, vol. viii. p. 589, seventh ed.

1st. What relation has the *actual quantity of "dry steam,"* in a given measure of air, to the insulating power of that atmosphere?

2nd. What relation has the *temperature* of such an atmosphere with its insulating power?

3rd. In what degree is insulation influenced by the *density* of the atmosphere?

4th. Has oxygen gas and dry steam a different insulating power from nitrogen, &c.?

The solution of *this* query would not serve *our* purposes perhaps.

† An *uncoated* rod retained some remainder for 102 hours. Had the receivers been *perfectly* air-tight perhaps this would have insulated as well as the others.

ously) they would not collapse for five or ten minutes; and after these supporting wires had been charged, the straws continued *slowly* to *increase* in divergence during an hour or more sometimes*. This was proved by comparing them with natural undried straws.

I therefore tried many experiments upon straws *gilded* in various ways, but even these did not appear to afford such complete freedom from the above-mentioned defect as was required.

Passing over many details (tedious but not instructive perhaps), I will now describe shortly the apparatus, &c. which I call my registering (or night) electrometers, the results of many trials.

Three receivers, $5\frac{1}{2}$ inches high and 4 inches diameter, were fitted air-tight to ground brass plates at their bases and necks. In these the electrometers, supported as before, could be charged by means of moveable and insulated wires, without interfering with the air-tightness of the receivers, and they contained a rather larger quantity of the chloride.

In lieu of the straw electrometers recourse was had to a modification of my old instruments of fine wires†, very accurately straightened, and in order to prevent as much as possible dissipation, without materially increasing their weight, minute globules of gum-arabic were applied at their extremities, whilst they were electrified for the occasion.

A scale which could be read in terms of the standard voltaic electrometer was thus prepared: a slip of ivory was properly cut (to the radius of the wires) and fixed at one extremity of a ruler one foot long; the other end of the ruler carried a sight-piece, like C (fig. 5); this ruler was held in the hand, and the scale-end made to touch the receivers when used. The graduation was easily effected (not in *exactly* equal divisions of course) by marking on the scale (before engraving) the degrees of divergence of the wires, as seen through the sight, which corresponded with the divergences of the ordinary standard electrometer, placed in good conducting contact with these wire electrometers.

In order to compare these registers with each other and with the standard, the moveable insulated wires and the standard were placed in contact with an insulated horizontal wire, so that they might be all charged simultaneously; then their contact with the horizontal wire was suddenly broken, and at the same moment the contact of the moveable wires with the electrometric wires.

The following Table on the next page exhibits a specimen of the performance of these registers, called C, D, and E.

If a quarter of a degree of this scale be added for every hour which may elapse betwen the time at which any one of these registers was charged, and the time at which it is read, up to the 45th degree, we may perhaps be tolerably sure of knowing what the charge was within something less than a tenth of a degree (and this is a quantity which cannot be appreciated by any observation of a voltaic electrometer).

After the 45th degree (upwards) the loss per hour begins to increase in a much more rapid rate, and after the 90th uncertainty prevails, because *spirtings* "spruzamenti" begin, as Volta found in his electrometers.

However, the *nightly* charges of our conductor (after 10 P.M.) in serene weather seldom exceed 45 degrees.

New experiments must be made on this subject. In the mean time we apply these instruments to the purpose intended, and hope to improve our journal thereby. The particular mode of application and a more detailed

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* We have observed the same kind of effect (in much smaller degree) in the electrometers (exposed to the open air) in the observatory in *very* dry weather.

† Vide Descriptions of an Electrical Telegraph, &c., 1823, p. 33.

account of them will perhaps be a subject for report when the observations made with them are recorded.

A sort of minute Leyden jar, mounted in the chloride as above, retained a remainder of a low charge 15 days, but it lowered the tension of the conductor from 2 to 5 degrees, and more accordingly as the electricity of the air was *frequent* or *slow*.

1844.	C.			D.			E.			Mean Loss of the 3 per hour.
Day.	Hour.		Loss per hour.	Hour.		Loss per hour.	Hour.		Loss per hour.	
June 15.	4 20	57°·5		4 0	65°		4 47	57°·5		
,,	6 50	55		11 45	62·5		10 7	55		
,,	12 41	52·5		16 30	60		17 44	52·5		
,,	16 29	50								
,,	....	......	0·63	....	......	0·4	....	......	0·38	0·47
16.	6 23	45		5 0	55		8 10	47·5		
,,	15 10	42·5		13 55	52·5		18 40	45		
,,	....	......	0·28	20 20	50	0·33	....	......	0·24	0·28
17.	7 45	37·5		4 15	47·5		4 45	42·5		
,,	16 57	35		13 23	45		17 0	40		
,,	....	......	0·27	....	......	0·27	....	......	0·2	0·25
18.	5 0	32·5		7 20	40		4 15	37·5		
,,	15 17	30		17 0	37·5		15 20	35		
,,	....	......	0·24	....	......	0·26	....	......	0·23	0·24
19.	4 0	25		5 30	35		4 0	32·5		
,,	17 0	22·5		13 0	32·5		13 45	30		
,,	....	......	0·2	....	......	0·33	....	......	0·26	0·26
20.	4 45	20		4 0	30		8 0	25		
,,	17 0	17·5		11 45	27·5		17 0	22·5		
,,	....	......	0·2	20 30	25	0·3	....	......	0·28	0·26
21.	4 0	15		5 0	22·5		4 0	20		
,,	14 17	12·5		13 30	20		16 0	17·5		
,,	....	......	0·25	....	......	0·29	....	......	0·2	0·25

6. EXPERIMENTS ON INDUCTION, &c. BY ATMOSPHERIC ELECTRICITY.

Professor Wheatstone has several times repeated, in a very striking and pleasing manner, the experiments of Herr Erman and M. Peltier, &c. relative to this subject, and such kinds of operations have never failed when tried upon the flat roof, and in fine or appropriate weather.

The electroscope used was of Bennet's kind but square, and the conductor about 15 inches high, with a hollow copper ball on its summit of 3 inches diameter.

I have also occasionally substituted a "*solfanello*" (following Volta) for the ball, in order to exhibit the difference between electrisation by induction and absorption.

In the first case, after the electrometer has been touched in its high position, the leaves do not (of course) diverge again until absorption takes place, after the lapse of a considerable length of time, and when the insulation is extremely good. In the second case they instantly begin to diverge, and attain to a greater divergence than by induction, all else being equal.

Small gold leaves being very liable to derangement, &c., and being less applicable to a scale-measurement than straws, I have constructed a pair of voltaic electrometers for these experiments (and others requiring portability), similar to those of figs. 4 and 5, excepting that the cover T is screwed upon the case, and a very *light* conical-jointed tube about 3 feet 3 inches long can be screwed upon the wire, which supports the straws, and either a hollow light ball or a *solfanello* can be fixed on the top of it. The glass tube S is longer and stronger, and protected from rain, dust, &c. by a cap. This pair of electrometers fits into a case and the conductor into a walking-stick. The conductor might be jointed and its length increased with great advantage.

7. Experiments on Frequency of Atmospheric Electricity.

By these terms is understood the rate at which a new charge rises to its maximum, after a former charge of an atmospheric insulated conductor has been destroyed.

The old experiments of Beccaria on this property appear to me to have been much less attended to than they should have been. It seems to form a sort of link between natural high-tensioned (frictional) electricity, and galvanic, or Voltaic or Œrstedic electricity (electro-magnetism).

We have as yet merely instituted a few very rough observations of this kind, not having obtained opportunities for prosecuting the inquiry in a satisfactory manner.

The apparatus employed consists partly of that described at p. 135. The two insulators (*a* and *b*) were carefully compared as to insulating power. An arm (of wood, which is not a proper material) projected from the cap of each, outside of the window of the room D (fig. 1), and to these arms were firmly lashed two exactly equal copper conical tube-conductors, carrying small and equal lanterns on their summits.

After abundant time had been given for these conductors to attain their maxima charges, one only was discharged, and the time which elapsed before that one acquired a new charge equal to the charge of the other is my measure of "frequency."

	Time.	Tension.	Frequency.	
	h m		′ ″	
May 2.	20 21	20	2 15	Fine clear evening succeeding a fine day.
,,	21 32	42	13 35	
May 3.	21 0	22·5	20 30	
,,	21 46	25	20 45	
May 6.	20 0	28·5	2 45	The evening fine and starlight, but somewhat cloudy.
May 8.	19 51	5	13 25	The weather dull and overcast.
May 9.	20 45	8	16 0	At 20^{h} dull and cloudy; at 21^{h} clear and starlight.
May 16.	20 55	7	3 0	At 21^{h} dull and overcast. The day had been fine but rather cloudy.

These few and imperfect observations serve to prove little more than that at different times and under different circumstances (of weather, &c.) *very great* differences in the relations of tension to frequency occur*. Fogs and heavy dews have always great frequency.

8. Pluvio Electrometer.

We are fully convinced that a hard shower of rain, &c. as frequently robs our conductor of large doses of electricity as that it brings them.

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* The first maximum charges, viz. 10° of these lower rods on the 8th of May at 18^{h} 55^{m} was *greater* by one degree than the charge at the same moment of the high conductor on the dome, but after the destruction of the first charge they never rose again to the same height as that of the high conductor by 5 degrees. On the 16th of May, at about 18^{h} 55^{m}, the lower rods at the time of their first charge exhibited a tension equal to that of the high rod, and the maximum charges afterwards were at 20^{h} 55^{m} 13 degrees lower. These singular facts might possibly be accounted for on principles by which I would explain the experiments of Erman, but shall forbear from theorising here.

A copper dish (vide fig. 1.) of 3 feet 6 inches diameter and about 6 inches deep, quite smooth and with a well-rounded ring on its edge, has therefore been very recently mounted upon one of our usual insulators, and we hope to observe some circumstances worth notice with this apparatus when we have time to pursue investigations of this kind.

9. Storm Clock.

It has been remarked in our MS. Journal that the difficulty of noting down the various and transient phænomena of a storm is too great for any single observer to overcome without assistance.

I have therefore projected a time-piece carrying an index down a long page of paper in half-an-hour, by which means, in lieu of having first to read the times by our chronometer and then to set them down, erroneously perhaps (in the hurry of the moment), the observer will have only to record the events as fast as they occur (nearly) opposite to the point of the index, *if he can* (for even this will be *sometimes* too much for one person to accomplish: Beccaria employed *several* observers frequently on such occasions).

This instrument is in progress.

10. New Coulomb Electrometer.

In my "plan," &c. sent to Mr. Wheatstone in November 1842, is described a proposed modification of Coulomb's electrometer, which seemed to possess great advantages for atmospheric electricity, and I constructed a rough kind of model which clearly showed that the project was feasible.

The principle consists in suspending a *conducting* moveable needle in lieu of the usual insulating needle, by a torsion *wire*, or by a pair of torsion *wires* (instead of Mr. Snow Harris's *silken threads*) in such manner as to be always in perfect conducting communication with a *fixed conducting needle*.

A drawing for a complete instrument of this kind was placed in the instrument-maker's hands in May. It is *now* nearly finished.

11. Spring Anemometer.

In order to know something about the force of the wind by simple inspection and without leaving the observatory, we have fitted a little slider to the part (A) elongated of fig. 17, which slider is made to rise or fall by the action of the wind on a set of flyers situated on the top of the wind vane, and by a spiral (volute) spring, &c.; but this arrangement is not yet complete.

Kew Observatory, Sept. 25th, 1844.

Sixth Report of the Committee, consisting of Sir J. HERSCHEL, *the* MASTER OF TRINITY COLLEGE, *Cambridge, the* DEAN OF ELY, DR. LLOYD *and* Colonel SABINE, *appointed to conduct the co-operation of the British Association in the system of Simultaneous Magnetical and Meteorological Observations.*

IN the arrangement of the subjects of this report, the plan of former reports having been found convenient will be adhered to;—and first respecting the

Antarctic Expedition.

The return of the Expedition, which took place very shortly after the meeting of 1843, has closed this branch of our report in a manner the most highly gratifying, whether we regard the magnitude and geographical interest of its discoveries, the vast harvest of magnetic and meteorological observations it has secured, the extent of ocean traversed, and the consequent importance of the data it has furnished towards the completion of the magnetic survey of the globe in its most difficult points; or, lastly, the triumph of skill, conduct and perseverance on the part of the Commander of the Expedition, and every one concerned in it, which have under Providence been the means of conducting so arduous and prolonged a struggle with every material obstacle to a glorious and happy conclusion.

The results of the magnetic observations made during the second year of the operations of this Expedition will shortly appear under the form of a 'Sixth series of Contributions to Terrestrial Magnetism,' by Colonel Sabine, already printed for the Second Part of the Transactions of the Royal Society for the current year. During this period, the ships, setting out from Hobart Town and visiting Sydney and New Zealand in their progress, explored a second time the great Icy Barrier in lat. 78° south, which had stopped them in the former year, and which again resisted their efforts either to penetrate it or to turn its eastern extremity. Quitting it at length and keeping nearly on the 60th parallel of south latitude, they crossed the whole breadth of the South Pacific to the Falkland Islands, where the observations of that season terminate. Those of the last year of the Expedition not having yet been placed in his hands, Colonel Sabine has forborne to anticipate the principal part of the conclusions suggested by the materials thus brought under discussion, until supported by a complete and general review of their whole mass. There are, however, some points of prominent interest which have emerged from the discussion of the first two years' observations which ought not to be passed over in silence.

In the first place, Colonel Sabine considers it to have been rendered almost certain, that in the two ships employed in the Expedition, and probably therefore in all ordinary sailing vessels, there is little or no appreciable amount of *permanent* magnetic polarity (though in steamers or iron ships the case may be otherwise), but that the *whole* of the transient polarity induced in the iron by the earth's action at any given moment and locality is not *instantaneously* destroyed and exchanged for a new magnetic state on a change of geographical place or angular position, though the greater part of it is so. A residual polarity lingers as it were in the iron of the ship and fades out more slowly, so that the vessel carries with it into every new point of its course some trace and impress of the terrestrial magnetism of those which it has left. This consideration, joined to the converse proposition, which it renders exceedingly probable (viz. that the magnetism which thus requires time for its destruction is also not instantaneously developed), would render the problem of deducing rigorous results from observations made during voyages a very difficult one, were it not that the portion of magnetic power which thus lingers in the iron is extremely small compared with that which obeys the laws of soft iron in its instantaneous generation and destruction.

Another conclusion of a very general and positive character respects the forms of the magnetic lines in the southern hemisphere, especially those of declination. From the assemblage and projection of all the observations of this element, Colonel Sabine is led to the conclusion that the system of magnetic ovals in the southern hemisphere is really a double one, completely analogous to that which prevails in the northern; so that the two hemispheres do actually possess, with respect to each other, a converse or complementary character indicative of a certain symmetry in the disposal of the magnetic forces or in the action of their causes.

The situation of the Isogonic lines of the South Pacific at the present epoch, as deduced from these observations, and brought into comparison with the best evidence we possess of the situation of corresponding parts of the same lines, or which comes to the same thing, of lines cutting several of them continuously at right angles, fully corroborates and bears out another general proposition, viz. that the march of the magnetic phænomena in this region of the globe is steady, rapid, and *in a westerly direction.*

In projecting the lines of equal intensity deduced from the Antarctic observations, Colonel Sabine has been led to compare them with those theoretically deduced by the numerical interpretation of Gauss's formulæ. The most important distinction between M. Gauss's isodynamic and those resulting from observation is, that Gauss's are nearly circular curves round a *single centre,* whereas those of observation appear to be two distinct systems of curves. In the northern hemisphere the two systems are *separated*; in the southern, the progress of secular change appears to have brought them to run into each other, producing, by the conjunction of two ovals, one very lengthened oval, in which however the trace of the double curvature is still recognizable. The two foci in the south appear to have nearly the same values as those in the north.

British Colonial Magnetical and Meteorological Observatories.

The volume of the observations made at the observatory at Toronto in Canada, from its commencement to the end of 1842, has been for some time in the press, and will be distributed at home and abroad in the course of the winter. The volumes containing the observations at Van Diemen's Island, the Cape of Good Hope and St. Helena to the same period, are in a very forward state of preparation, and will be printed and circulated with no other delay than such as may arise in the printing and engraving such voluminous works. The volume for Toronto will include the comparison of the simultaneous observations made in the group of stations on the North American continent. The Van Diemen Island volume will compare the observations at Hobarton with those of the Antarctic Expedition at many points of the southern hemisphere, the two together representing the magnetic phænomena which occurred over a considerable portion of that hemisphere, on the prescribed days and instants when the observers in Europe, Asia and America were recording, each at his own station. With St. Helena and the Cape of Good Hope will be grouped the observations made on the same system and with the same instruments by the French observers at Algiers, which have been supplied for that purpose by the kind intervention of M. Arago. Cadiz, from whence observations are also expected, ranks also with this group, which may be viewed as representing the portion of our western hemisphere intermediate between the Falkland Islands and Cape Horn (where the Antarctic

Expedition passed several months), and the North American group collected in the Toronto volume, as well as the European group collected in the 'Resultate' of MM. Gauss and Weber.

So much is yet prospective in regard to publication, that *comparatively* little can be at present ventured in regard to conclusions. The only portion of the observations which is yet before the public, viz. observations on days of unusual magnetic disturbance 1840, 1841, does however afford some conclusions which may be taken as an earnest of the fuller harvest. The most important of these is the fact, shown in the preface of that volume, of the *universality* of the disturbances of the higher order. The establishment of so important a general law, on evidence which may be considered to have placed it beyond a question, is a happy augury of what may be expected from a combined system of observation, of which it is the first fruits.

Further, it was shown from the observations in that volume, that though these great disturbances are universal in their occurrence, yet their magnitude is clearly modified by *season* and by other local causes; so that for example, while the northern and southern hemisphere participate in every great disturbance, the influence of summer in the one and winter in the other is clearly traceable.

There are also facts stated in regard to the periodical march of the magnetic elements at Toronto and Hobarton, valuable in themselves, but yet more so in the evidence they afford of the *exact* determinations which will be everywhere accomplished in this branch of the phænomena.

Another conclusion has also been drawn in regard to the great disturbances, which will have a more full development in the Toronto volume. It has been shown that the effects, as manifested by the movement of the magnetic instruments at all places of observation, of a disturbance taking place in all parts of the earth at the same time, were not the same,—thus limiting the distance of the superimposed force which produces disturbances coinstant in respect to time, but differing in respect to direction and intensity, at stations remote from each other. The mode of computing the direction and amount of the superimposed disturbing force from the observations at a single station is also stated.

In the Toronto volume, the term observations of the three American observatories for the three years ending in December 1842, all showing the closest harmony with each other, are compared with those at Prague, taken as a type of the European group: the comparison exhibits frequent unequivocal evidence of connexion in many of the larger irregular movements. In such case the simultaneous movements in Europe and America take place sometimes in the *same* direction, as by a force operating upon both continents from the same quarter; and sometimes the European and American movements are in opposite directions, as by a force operating intermediately between the two continents. It is obvious that, if the observations were *instantaneous* as well as simultaneous, the locality of the disturbing force might be immediately deducible. Without, however, going further into anticipation of what may hereafter be concluded from observations not yet before the public, there is ground, in what is already known concerning them, for expressing the hope that important conclusions will be drawn in respect to the locality of the disturbing causes, especially when the observations made with the most recent magnetometers, constructed to exhibit *instantaneous* effects, shall come to be considered. In our present ignorance of the nature of the causes of these phænomena, we are surely advancing in the proper, legitimate and philosophical mode of ascending to them by this careful study of their effects.

In meteorology, a system of careful observation with compared instruments steadily maintained at every hour of the day and night could not fail to accomplish the solution of many problems in vain attempted by a large expenditure of desultory labour. The mean quantities, the diurnal and annual variations of the temperature, pressure of the gaseous atmosphere, and tension of the aqueous vapour, with their many concurrent circumstances of wind and weather, must be determined with no remaining uncertainty for each station, if the system be continued in operation for a sufficient time. The definite and conclusive character of the meteorological results obtained by the system of observation which we have adopted, appears to be strongly in favour of the extension of the system. By the comparison of such definite conclusions obtained in different parts of the world, by their points of agreement and of difference, reasonable expectations may be cherished that we shall speedily be enabled to advance the science of meteorology to a degree unexpected at the commencement of these operations. That the spirit to accomplish this is alive, and that an organization has now been established and is *recognised*, by which a proper direction and guidance may be supplied to that which individual zeal is desirous to effect, will appear from a consideration of what has passed with respect to the establishment of observatories in Ceylon, Newfoundland and elsewhere.

New Series of Observations at Fixed Stations proposed or recently commenced.

As regards the first of the above-named stations (Ceylon), a proposal was submitted in April of the current year to the Governor of that colony by Captain Pickering of the Royal Artillery, and Dr. Templeton, Assistant-surgeon R.A. (the former of whom had been instructed in the nature of the observations and the use of the instruments at Woolwich), for the establishment of a magnetic and meteorological observatory at Columbo in that island, a station of obvious interest and importance. The proposal was most favourably received by His Excellency, who recommended it to the favourable consideration of the Secretary of State for the Colonies, with the additional suggestion of an astronomical observatory, declaring his readiness, if approved, to devote to it local funds adequate to its maintenance in activity, if once established and furnished with instruments. The subject is at present under the consideration of government, and a subject of official correspondence; and in case of a favourable issue, the Royal Society have been applied to for the loan of the magnetometers prepared at the cost of the Wollaston fund for the Hammerfest Observatory, which have never been claimed by the Norwegian government, and which station is for the present to be regarded as in abeyance.

A similar arrangement is in progress for Newfoundland, and indeed more advanced, the magnetical and meteorological instruments having been sent there, with a company of artillery proceeding on their tour of service, one of the officers of which, Lieut. Brittingham, has been instructed in their use, and will remain at that very important station probably for some years. Some small expenditure for instruments may possibly have to be defrayed from the grant of the Association to this Committee at a future stage of the business.

During the printing of this report a prospect has been opened, through the intervention of Sir William Colebrooke, Governor of New Brunswick, seconded by the representations of Capt. Owen, R.N., of the establishment of an observatory at Frederictown in that colony, a station remarkable for its brilliant aurora borealis, of which we hope to have further mention to make in a future report.

Arrangements are also in progress, and with good prospect, for a meteorological and in part magnetical station at the Azores.

The German apparatus belonging to the British Association has been altered in some respects to give it a degree of efficiency which it had not before, and has been sent to Dr. Locke at Cincinnati, who has acknowledged its receipt, which will in future be another station for the term observations.

Magnetic Surveys and Itinerant Observations in progress, or about to be undertaken.

North American Survey.—The great interest which attaches to the survey of the difficult and inhospitable country undertaken by Lieutenant Lefroy, will render a sketch of his proceedings, so far as they are at present known, especially acceptable. By letters written by him from York Fort in the autumn, it appears that he had proceeded thence from the Lac de la Pluie, a distance of about 500 miles, in the direct course towards the point of perpendicular dip, during the whole of which journey he had found the total intensity to *diminish* progressively. Later accounts have been very recently received from him from Athabasca, where he was to pass the winter, and whence he originally contemplated retracing his steps by a more inland route to the lake above-mentioned on his way to Red River.

At the date of those accounts Mr. Lefroy is making hourly observations throughout the twenty-four hours, with one assistant, observing the changes of the declination, the horizontal force, and the inclination, *i. e.* the declination and bifilar magnetometers, and the induction inclinometer. He will probably complete four or perhaps five months' hourly observations before leaving Athabasca. After leaving, he says,

"My plan is to go down to Mackenzie River in March on snow shoes; when there, there are two prospects, one is to return in May to Slave Lake, and thence come here by the very first navigation, the other to Great Bear Lake, and return with the Mackenzie River barges, which do not leave Fort Simpson until near July. In either case the next step is to ascend Peace River and cross by Lesser Slave Lake, &c. to the Saskatchawan; but if I take the latter course I cannot expect to reach Red River before the very end of September, which will endanger my return to Canada by open water, and wholly preclude the idea of returning by Moose Factory. The latter is not of much consequence, as if I return to this country it will be perfectly easy to go by Moose and yet reach Lake Winnipeg in time for everything. A little therefore will depend upon the seasons; if the spring promises to be a very early one and allows the Mackenzie River boats to come off before their usual time, I shall perhaps venture on the latter; at present I am most inclined to the former. In either case I shall get a few weeks' transportable observations in a more northern latitude, which is desirable."

Arrived at Red River, he will find instructions to observe, if possible, the decrement of magnetic intensity from its maximum in the Rainy Lake in a westward direction, thus completing a system of lines radiating out from the maximum in the northern, eastern and western directions (the eastern line being already secured). Dr. Locke's observations, which are now printing at Philadelphia, will furnish the fourth line. The full development of these important features, which will establish in a very approximate manner the central point of the isodynamic ovals in this quarter, must await the assemblage and discussion of the whole mass of materials in process of collection*.

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* While this report is passing through the press, a letter, dated 22nd Nov., addressed by Lieut. Lefroy to Capt. Sabine, announces his safe return to Toronto, having completed his survey from the Slave Lake by Assiniboin, Edmonton, down the Saskatchawan River to Carlton and Cumberland, and thence by Norway House, Fort William, Sault Ste Marie and Penetanguishene, to his entire satisfaction. A maximum of intensity occurs near the lake of the woods.

Completion of the Antarctic Survey.

The contributions of the officers of the Surveying Expeditions in the Hydrographical department of the Admiralty have already done the greater portion, and promise to leave nothing to be desired in respect to that part of the ocean comprised between the Equator and the 50th degree of south latitude; so that it might at all events have been confidently expected that in a year or two from the present time the sole remaining desideratum of importance unprovided for would be that part of the higher parallels not traversed by the Antarctic Expedition, viz. the region comprised between the meridian of Greenwich and the 130th degree of east longitude, and extending southward to the edge of the ice. The survey of this portion of the Antarctic ocean, however, has been undertaken by Lieutenant Clerk, R.A., of the Ordnance Magnetic Observatory at the Cape, who has zealously volunteered his services to that effect, and at the instance of the Royal Society has been liberally furnished by the Admiralty with the nautical means of executing his design, a vessel having been taken up and placed at his disposal for that express purpose*.

Proposed Survey of the Eastern Archipelago and China Seas.

Animated by a kindred spirit, Lieutenant Elliott, superintendent of the East India Company's magnetic and meteorological observatory at Singapore, has volunteered a survey of the Malayan Archipelago, proposing to visit Malacca, Penang, the Tenasserim Province and Sumatra, to undertake a minute survey of Java, to procure determinations in Timor and Borneo, to attempt the Philippines, and to observe at all the open ports in China. The especial importance of such a series of observations need hardly be insisted on; and although the East India Company have not felt themselves (in this single instance) justified in complying with the suggestion, no doubt for reasons of the most valid nature, and arising probably out of the peculiar political relations of some of the countries proposed to be visited, your Committee have considered that they would not be doing justice to the energy and devotion of Lieutenant Elliott, or to his discernment of what would be scientifically desirable, in originating the proposition, were they to forbear making mention of it in this report.

Continental Surveys—Austria, Sweden, &c.

During the last summer, M. Kreil, director of the magnetic observatory at Prague, travelled over a considerable part of Bohemia, making geographical and magnetical determinations at many points, an account of which will be found in the sixth delivery (heft) of Lamont's 'Annalen.' The same distinguished observer has more recently applied to the Emperor of Austria for the authority and means to travel over and execute a magnetic survey of the whole empire of Austria, an application which His Majesty has liberally acceded to, and granted the requisite funds, so that in a few years we may hope to be put in possession of a survey of that great monarchy, equalling or excelling what has been done for any other great portion of the European continent.

M. Angström, astronomer of Upsala in Sweden, leaving Munich in the early part of the season, is understood to have undertaken a series of observations with a magnetic theodolite at all the principal stations on his return to Upsala. And M. Lamont proposes to connect his own observatory at

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* The Pagoda barque, 360 tons, has been chartered by government for this service, manned with forty men, under Lieut. Marshall, to sail the first week in November. (Note added during the printing.)

Munich with London by a similar chain of observations of the magnetic constants at Stuttgard, Tubingen, Heidelberg, Manheim, Mayence, Cologne, Aix la Chapelle, Brussels and other places.

Itinerant Observations not in the nature of Formal Surveys, Naval Observatories, and other Local Determinations.

Portable magnetometers, accompanied with Lieutenant Riddell's instructions for their use, have been sent not only to the fixed observatories, but also to Sir E. Belcher in China, Captain Blackwood in Torres Straits, Captain Graves at Malta, Captain Barnett at Bermuda, Captain Otter on the north coast of Scotland, and Captain Bayfield in the St. Lawrence. Two sets have also been ordered for the American Coast Survey, the one to be used by Prof. Bache, the other by Prof. Renwick. The officers of the Royal Artillery at Newfoundland are also similarly provided. In all these cases, the instruments, previous to their despatch, have been carefully examined at Woolwich, and in several instances the constants of temperature, &c. determined for each magnet, and a proper supply of blank forms for the entry and work of the observations adjoined. And we have reason to expect that term observations and absolute determinations will be received from all the quarters above enumerated. Valuable contributions of this nature from Captains Blackwood, Belcher and Otter have already come to hand.

Publications relating to Terrestrial Magnetism.

Among the more generally useful and practically important publications relating to this science, must be considered the elaborate and admirably arranged and digested work of Lieutenant Riddell above alluded to, entitled "Magnetical Instructions for the use of Portable Instruments adapted for Magnetic Surveys and Portable Observatories." Full and complete instructions of this nature, adapted to the species of instruments now become of universal or nearly universal employment, whether intended for differential observations or absolute determinations at fixed stations, or for magnetic surveys and other local operations, had long been greatly wanted; and in fact great inconvenience had been experienced, on all hands, owing to the want of an authentic digest of the kind adapted to the present advanced state of the subject. It was reasonable to expect that, in a subject so new as magnetism, some of the instruments and methods by which the investigation was in the first instance proposed to be carried on, should have proved inadequate to their purposes. Such has been found to be the case, particularly in reference to that highly important branch of the inquiry, the secular changes. The indisputable evidence of inadequacy, the contrivance of instruments or methods to be substituted, the execution of those instruments, their trial and proof, and their subsequent transmission to the stations with full directions for their use, is all a work of time, and *pro tanto* has tended to diminish the period for which the observatories can be considered to have been thoroughly effective for their proposed objects; all this has proved an anxious as well as very laborious part of the occupation of the Ordnance establishment, of which the strength was calculated solely for the duties of reduction and publication. There being no head-quarter observatory, where such questions would be examined and deficiencies supplied, a large portion of the attention of that establishment has been necessarily occupied in this work. The work in question will show the labour that this has occasioned; it occupied indeed, almost exclusively, for more than a twelvemonth, the thoughts and time of Lieutenant Riddell, Assistant Superintendent, whose previous employment as director of the Toronto observatory, for the first year of its establishment, gave him a peculiar qualification for the task. It is satisfactory, however, to be assured, by the results which are daily arriving from the observatories, that it has been time well-bestowed, and we may pretty confidently say that assured secular determinations will date from the commencement of the present year at all the observatories under the Ordnance superintendence. One consequence, which may fairly be attributed to this work, and to the facilities thereby afforded for the acquisition of a perfect knowledge of the processes, has been the great increased demand for magnetic instruments since its publication, which exceed the power of the opticians chiefly conversant with their construction to meet.

The valuable 'Annalen fur Meteorologie Erdmagnetismus,' &c., published by Dr. Lamont, is continued, and the sixth and seventh numbers (for 1843) have reached the Committee. They contain the magnetic term observations for 1842, observed at Milan, Munich, Prague and Kremsmünster; M. Weise's observations at Cracow for 1841 and 1842; the result of M. Kreil's magnetic determinations in Bohemia, already mentioned; the magnetic perturbations observed at Munich in 1842, and a vast collection of valuable meteorological contributions from all parts of Europe, of which the great length to which this report would thereby be extended alone prevents us from presenting an analysis.

The publication of the Russian observations, whether magnetic or meteorological, at the stations Petersburgh, Catherinenbourg, Bogoslawsk, Lougan, Zlaouste, Barnaoul, Nertchinsk, Kasan and Pekin, is complete up to the end of the year 1841, and forms indeed a magnificent contribution to the sum of science, worthy in every way of the greatness of the empire which has produced it, and reflecting the highest credit on the indefatigable exertions of M. Kupffer, the superintendent of the Russian observatories. The observations from Pekin are meteorological only, and are of course of great interest, though affected in some points (especially in what relates to the march of the hygrometer) by the social peculiarities of so vast a metropolis, such as the practice of copiously watering its streets in the summer, &c.

The third and fourth volume of the magnetic and meteorological observations at the Prague observatory, under M. Kreil, has also appeared, and has been received by your Committee. The meteorological observations in these volumes, as well as those in Lamont's 'Annalen,' and the records of the Russian observatories for several years, are at present undergoing collation by Mr. Birt, with a view to the tracing the progress of remarkable atmospheric waves, in a mode presently to be more particularly referred to.

The 'Annals of the Royal Observatory of Brussels,' vol. ii. recently published under the direction of M. Quetelet, is a most valuable contribution to meteorological science, containing the assemblage of such observations for the years 1837 to 1840 inclusive, in detail for Brussels and in summary for Alost and Ghent, together with determinations of the magnetic declination and dip for the same period, those of the declination for 1840 being diurnal, at four hours daily. The magnetic term observations for 1842, observed at Brussels, are printed in the 15th and 16th volumes of the 'Memoirs of the Royal Academy of Brussels.' These volumes contain also the meteorological horary observations made at the summer solstice and both equinoxes of 1842, at no less than forty-two principal European stations, in continuation of the series of equinoxial and solstitial observations, in which M. Quetelet has taken an especial interest. These interesting and important observations have subsequently, by the praiseworthy exertions of M. Quetelet, seconded by the zeal and interest of his numerous correspondents, been extended to no fewer than eighty stations. Their publication has been continued or provided for up to the end of 1843, but owing to some difficulties which have unfortunately since interfered and which are understood to have thrown a serious obstacle in the way of their future publication by the Academy, it is greatly to be feared that the course of this series of valuable records may be suspended or abandoned, to the great regret of every meteorologist.

The magnetic and meteorological observations made at the Royal Observatory at Greenwich, under the direction of the Astronomer Royal, during the years 1840 and 1841, have been printed by order of the Admiralty, in full detail, uniformly with the astronomical observations made at that great national establishment, but in a distinct volume, and it is understood that the subsequent observations will be presented to the public in a like liberal form. The volume is prefaced with a valuable introduction from the pen of the Astronomer Royal, describing every part of the apparatus and the mode of using it. One important characteristic of this station, as it now exists, is the apparatus for observing the atmospheric electricity, a department of meteorology of equal importance and difficulty, and which has hitherto been very inadequately studied.

The diminution of magnetism in steel needles by time as well as by temperature, has been made the subject of a short but valuable treatise by Professor Hansteen, 'De Mutationibus quas subit Momentum Virgæ Magneticæ partim ob Temporis partim ob Temperaturæ Mutationes,' which, although printed in 1842, has only come to our knowledge since the date of our last report. The inquiry into the temperature corrections, being matter of *experiment*, is easy in comparison with that of the changes effected by time, which are matter of pure observation, and partake therefore of all the disadvantages which affect purely observational sciences. The conclusion which Professor Hansteen draws relative to this part of the subject is, that *the decrements of intensity form a geometrical series when the time increases arithmetically*, and *that the magnetic moment continually approaches to a fixed limit*, to attain which of course an infinite time is necessary, but which, practically speaking, would appear to have been approached with a higher degree of approximation, at least for the great majority of cases (seven out of nine) which have formed the basis of Professor Hansteen's conclusions within two or three years from the epoch of their magnetization, and in some instances much more speedily, according to the hardness of the steel and other causes.

Dr. Lamont, director of the observatory at Munich, has published a summary of the results of the observations made at that station during the years 1840, 1841, and 1842. Of these, the declinations previous to June 1841, and the intensities previous to November in that year, are regarded by him as of inferior value to those subsequent to those respective epochs. The daily fluctuations of the declination and of the horizontal intensity, deduced from the assemblage of the monthly means obtained during the available portions of these years, and of the *mean* declination from 10 to 10 days during the whole period (which he considers to be unaffected by those causes of uncertainty which affect the hourly observations during the earlier portion of it), are tabulated and graphically projected. In the projection of the daily fluctuations of the declination, the double diurnal maximum and minimum as well as the periodically varying influence of temperature in summer and winter are strikingly apparent. In that of the intensity the morning minimum is the most conspicuous feature, and though the summer and winter inequalities are also perfectly distinct, the daily course of the curves, as Dr.

Lamont justly remarks, is affected with undulations which can hardly be referred to the *direct* action of the solar heat. The course of the mean declinations exhibits a continual and tolerably though not quite uniform decrease of about 7′ per annum, but without any indication of regular periodical fluctuation, either annual or otherwise.

The 'Annales de Chemie' (vol. x. 3rd series) also contains a similar summary, not accompanied however by graphical projections, by M. Aimé, of the results of nineteen months' consecutive magnetic observations made by him at Algiers, from June 1841 to Dec. 1842 inclusive. These exhibit, as respects the declination, only one diurnal minimum, varying in epoch with the season from 7^h to 8^h 30^m A.M., and a single maximum varying also in epoch, but contrarywise with the season, from 2^h P.M. to noon. The fluctuation is nearly double in summer as compared with its amount in winter. The correspondence of the march of this element with the temperature has appeared to M. Aimé so exact, that he suggests the observation of it continuously on the occasion of solar eclipses as an object of especial interest.

The present change of declination at Algiers appears to be about $2\frac{1}{2}'$, decreasing. By some observations reported by M. Aimé as having been made in 1832 and 1833 by Captain Berard, the needle may be presumed to have attained its maximum westerly declination about that epoch. The inclination diminishes at Algiers at the rate of about 6′ annually.

Meteorological Department.—Discussion of Meteorological Observations.

At the last meeting of the British Association, Sir J. Herschel, acting as a committee for the reduction and discussion of the meteorological term observations for 1835–38, reported among other matter, that by the aid of these observations it had proved practicable, in specified instances, to trace the progress and to assign the magnitude, direction and velocity of atmospheric movements in the nature of waves over nearly the whole of Europe, and that in a manner which, if pursued further, could hardly fail to afford real and valuable additions to meteorological science. Being obliged however, from the pressure of other occupations, to leave the inquiry at this point, Mr. Birt volunteered to continue it under the auspices of the Association, and was accordingly added to this committee for that purpose. The progress made by him in it will be appended in his own words, as part of this report, accompanied with a letter explanatory of his views on the subject, and with models of certain atmospheric waves in several successive states of their progress over Europe, which will be submitted to the Physical Section for their inspection. [See Mr. Birt's Report in this Volume.]

In the discussion of meteorological observations, the most serious obstacle, and that of the most formidable and repulsive character, is the enormous mass of calculation (necessitating transcriptions, &c.) required for their adequate reduction and preparation for the uses of the theorist; while, on the other hand, the method of inductive inquiry, which seems most applicable to the subject in its present state (the "Method of Curves," as it has been termed by an eminent writer on inductive science), requires the observations, when reduced, to be in a great variety of cases projected on paper in the form of diurnal, monthly or annual curves. On the other hand, such is now the perfection of every description of mechanical workmanship, and such the profusion in which the talent of mechanical contrivance is actually found to be disseminated among practical and theoretical persons in every class of life and in every line of human research or business, that the time is clearly arrived when arrangements of mechanism may be safely relied on to supersede the necessity of an immense mass of laborious and exhausting penmanship and computation. Self-registering instruments henceforward will prove yearly more and more the main dependence of meteorological inquiry, and indeed of inquiry in every department of science in the same phase of its progress: and their improvement, simplification and adaptation to the purposes of affording mean results on the one hand, and on the other the tracing out of curvilinear projections (the true "collective instances" of the Baconian philosophy) in a state ready for immediate use, ought to be regarded as one of the most important, perhaps *the most* important point to which mechanical ingenuity, guided by scientific knowledge, can be directed. The great object which ought to be kept steadily in view, is so to dispose the apparatus that *corrected results* shall be registered, if possible, and if not, that the corrections to be applied shall be registered *at the same instant, and on the same scale* with the observed elements, so that they can be readily applied to the projected curves by mere mechanical or geometrical superposition.

In this point of view a barometer which shall register its readings *corrected* for temperature would be of the utmost value. This does not appear beyond the reach of a moderate expenditure of thought*, and your Committee would earnestly recommend it to the consideration of artists.

Meanwhile it is with satisfaction that we refer to two constructions of self-registering barometers which have recently come to our knowledge:—one by Mr. Bryson, recently published in vol. xv. of the Transactions of the Royal Society of Edinburgh (to which apparatus he has since added a self-registering thermometer for the corrections, and a self-calculating disc attached to the reader, which exhibits the monthly means without calculation): the other instrument of the kind in question is the invention of M. Kreil, director of the observatory at Prague, who terms it a baro-thermometragraph, and who has also constructed a similar instrument (the thermo-hygrometragraph) for registering hygrometric indications. An instrument of this kind is now on its way to this country, having been constructed under the immediate superintendence of its inventor.

Finally, your Committee beg to recall to the recollection of the Association, that the duration of the magnetic and meteorological observations now in progress will cease with the year 1845, and that therefore it will be highly necessary that before that time—and in fact, if possible, at or before the next meeting of the Association,—the important question should be seriously taken into consideration, whether any endeavour ought or ought not to be made to obtain from the several governments which have supported the existing observatories further support—a very grave question, which has been already distinctly brought under the notice of your Committee by one of their most active coadjutors, M. Kupffer, director of the Russian magnetic observatories, and which it is highly proper should be considered in every point of view

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* An approximate compensation by the counteracting pyrometric expansion of an *invariable* length of mercury or lead is easily accomplished, but this would be subject to occasional error, amounting to nearly one-fifteenth of the total amount of the temperature correction. The pyrometric compensating column must be variable in its length in the ratio of the uncorrected length of the mercurial column, measuring the pressure. If however the instrument be mounted in a situation of which the variations of temperature are very slight, as in a cellar, or at the bottom of a mine, shaft, or even a well (which, as there is no occasion to approach it, except for the purpose of renewing the cylinders, would be liable to little objection), the error thus entailed would be so reduced in effect, as to disappear, for any but the very nicest purposes. Indeed the barometric part of the apparatus might be buried in the earth (allowing only enough access of air to propagate the pressure), the registering apparatus only being above ground.

with an earnestness commensurate both to its scientific importance and to the large and liberal manner in which that support has been already granted.

As respects the expenditure of the Committee, the annexed statement will show the amount of their grant expended and the purposes for which the outlay has been incurred.

Signed on the part of the Committee,

J. F. W. HERSCHEL.

APPENDIX.

Letter from Professor Boguslawski to Lieut.-Colonel Sabine.

"Breslau, 1844, September 18, 139.

"MY DEAR SIR,—With reference to your letter of the 20th of February, and to the verbal communications lately made to you by Sir Bernhard Hebeler, Knt., Consul-General to His Prussian Majesty, I have now the honour to inform you that I shall forward in a few days to Mr. Oswald, our Consul-General at Hamburg, the first part of the magnetic observations made at this place. They will be sent by the mail, being exempt from postage (until twenty pounds Pruss.) as far as Hamburg. I expect you will have arranged with Sir Bernhard the way how to receive the present, as well as the following parts, in the least costly manner; and you will also please to give your instructions to Mr. Oswald, or communicate them through Sir Bernhard.

"As the first two books of the year 1840 contain only the two terms of August and November, (the monthly terms only having been observed without interruption from January 1841 until now,) I should have liked to send you at least the observations of the year 1841, particularly as not only these, but likewise those of 1842 and even part of 1843, are completely entered, but the drawing of the curves is not yet finished. I have some objection to forward the entered observations without undertaking the projection of the curves, which latter serve as a test and assist in discovering some little errors made in the entries. The two terms of the year 1840 may then be considered as precursors, and may serve to discover whether all is sufficient for reduction and comparison.

"In general the observations may be divided in two periods—the first until April term 1841 inclusive, and the second beginning from the May term 1841. Until April 1841 inclusive, the old four-pound declination-bar was alone in the magnetic cabinet; the other two instruments received by your kindness were in the great room of the observatory exposed to many permanent influences of iron masses in the vicinity, where the observations were made with them on the terms 1840, August and November; and 1841, January, February, March and April.

"On the May term 1841, all three instruments were united in the magnetic room, the declination magnetometer being then provided with the second bar which belongs to the bifilarium. However, on this term the mutual action of the bars could not yet be done away with, because the declination bar could not at that time have been definitively suspended. But at the June term 1841, the same had received a proper regulation, whereupon the mutual action was neutralised by a fixed bar which was placed immoveably, according to its force, at calculated distances from the other bars. Whether this compensation has remained correct I wish to examine again at the conclusion of the daily and monthly variation-observations, in order to begin then a series of absolute declination and intensity. The two active bars scarcely change the time of their vibration, and the compensation bar, which is an old bar, seems likewise to be of constant force.

"Since the 1st of January 1843, there have been made observations four times a day, without interruption, and with all three instruments. Perhaps I may succeed, in the last year of the co-operation, to continue the observations every two hours.

"The perturbations of the magnetic declination and intensity in the year 1844, viz.:

"February 1. I.; 2. D. I.; 17. I.; 28 (trace).
"March 2. D. I.; 4. D. I.; 5. D. I.; 7. D. I.; 30 A.M. and P.M. D. I.
"July 7. I. August 9. I.

have been so trifling that it is not worth while to mention them for the present, but they will be communicated hereafter.

"You shall not have to wait long for the observation books of the year 1841, and those of the year 1842 will be forwarded in a few months. I hope the entries of the observations of the year 1843 will also be finished in the spring of 1845.

"Sir Bernhard will have conveyed to you already my sincere thanks, as also those of the Silesian Society, for the Reports of the British Association till the year 1842 inclusive, which you had the kindness to remit me.

"I regret much that I am also this year prevented, for want of a substitute, to express to you personally my obligations and to follow your kind invitation in order to enjoy days of instruction at the Meeting of the British Association. I beg you will please to convey to them my best thanks and my apology.

"I remain, with sincere regard, dear Sir, your obedient Servant,

"*Lieut.-Col. Sabine.*" "HENRY VON BOGUSLAWSKI."

On the Influence of Fucoidal Plants upon the Formations of the Earth, on Metamorphism in general, and particularly the Metamorphosis of the Scandinavian Alum Slate. By Prof. G. FORCHHAMMER, *Professor of Geology and Chemistry, Copenhagen.* (Printed among the Reports by direction of the General Committee).

IT is for geology to explain, how the enormous quantities of matter, soluble and insoluble, which the numerous rivers carry to the sea, are re-deposited, and employed to form new beds on the crust of the earth. With the insoluble portion, comprehending by far the greater part of the substances which are thus carried into the ocean, geologists have indeed much occupied themselves, and have given satisfactory explanations by showing, that enormous beds of sand and clay owe their origin to this action; but hardly any natural philosopher has tried to explain, what becomes of the vast quantities of soluble substances which the rain dissolves from the solid earth, and ultimately carries into the sea. Among these substances, sulphuric acid, arising from the solution of gypsum, and silicate of potash dissolved during the decomposition of felspar, are the most important, though by no means the only ones that occur. If we consider that clay is produced by the decomposition of felspar, and that a quantity of alkali (principally potash) proportional to the clay must have been dissolved in the water, the question that must strike every observer is, where has this enormous quantity of alkaline substances gone, and into what combinations has it entered, since we find so very trifling a quantity of it in sea-water?

It is evident that there must be some great accumulating power, which again separates these substances from the water of the ocean, and deposits it in an insoluble state in the beds, which are precipitated on the shores, and at the bottom of the deep seas. In fact, similar instances of solution and precipitation have long been known and studied by geologists, and have become extensive means of explaining geological changes. Innumerable springs carry vast quantities of carbonate of lime to the sea, while all rivers contain more or less sulphate of lime; yet the analysis of sea-water shows only small traces of lime, but then we observe that the animals of shells and corals everywhere are busily employed in extracting this lime from the water, and that they ultimately deposit it in the form of solid beds of limestone. The reason why so little lime is found dissolved in sea-water, is exactly the same as that which explains why so small a quantity of carbonic acid occurs in the atmosphere; although causes which are constantly operating are always supplying it with this substance, which is absolutely necessary for vegetable life. Plants deprive the atmosphere as fast of its carbonic acid, as subterranean heat, combustion and animal life produce it. In like manner, the lower animals extract the lime as quickly from sea-water, as rivers and submarine springs provide it, and there must necessarily be a similar cause constantly depriving sea-water of its potash and sulphuric acid, which so many and constantly acting decompositions ultimately convey to the ocean.

Marine vegetation has, in a geological point of view, but little attracted the attention of philosophers, and while land plants play a necessary part in every geological system, the whole vegetation of the ocean has been left a blank, except as far as fucoidal forms have been an object of contemplation for those geologists who principally occupy themselves with fossil plants. Notwithstanding this neglect, the quantity of vegetable substances annually formed by fucoidal plants is enormously great; and what is very material, the quantity of mineral substances, in the form of ashes, exceeds very much that which land plants contain, and thus sea-weeds, on account of such *mineral* contents, must necessarily have a decided influence upon the formation and changes of beds. For this reason I deemed it necessary to analyse the ashes of fucoidal plants, chosen among the different families of that class, and from very different parts of the globe; which plants I owe to the kindness of my friends Professor Schouw, Dr. Vahl and M. Liebmann. The analysis was carried on in the following way.

The dried sea-weed was weighed, calcined, and the ashes weighed; though the quantity of ashes thus obtained is not very correct, owing partly to a quantity of carbonaceous matter which inclosed by the salts had escaped combustion, and thus showed the quantity of ashes to be greater than it was in reality. In other instances, the quantity appeared a little less than it ought to be on account of some carbonic acid, which had been expelled from the carbonate of lime and of magnesia; now and then a small quantity of the sulphates had been reduced to sulphurets, and thus likewise occasioned a loss. All these causes of trifling errors do not, however, affect the general result of the analyses. For to ascertain the constituent parts of the ashes, they were extracted by water as long as anything was dissolvable; and from this solution, after it had been *made acid* by nitric acid, or in some cases by muriatic acid, the sulphuric acid was separated by a salt of barytes, and when the sulphate of barytes had been separated, the excess of barytes was again thrown down by sulphuric acid. The lime was then precipitated by ammonia and oxalate of ammonia, and the magnesia (if any was present) precipitated by a solution of pure barytes. The precipitate, which consisted of sulphate and carbonate of barytes and of magnesia, was treated with sulphuric acid, and the solution which contained the magnesia precipitated by phosphate of soda and an excess of ammonia From the alkaline solution, which besides potash and soda contained an excess of barytes, the barytes was precipitated by carbonate of ammonia; there was afterwards added muriate of ammonia until the potash and soda were changed into chlorides, upon which the whole was evaporated and heated, for the purpose of expelling the excess of muriate of ammonia, and then the whole was weighed. In order to ascertain the quantity of potash, the salt was dissolved and evaporated with an excess of chloride of platinum, the dried mass dissolved in alcohol of about 40 per cent., and from the weight of the chloride of potassium and platinum, the weight of the chloride of potassium, and thus that of the potash, was calculated.

In most cases the weight of the soda was found by calculation from the weight of the chloride of sodium, which again was ascertained, by deducting the weight of the chloride of potassium from the total weight of the alkaline chlorides. In some instances, the quantity of chloride of sodium was determined, by mixing the alcoholic solution of chloride of sodium and chloride of platinum with sulphuret of ammonia; in order to precipitate all the platinum, evaporating the liquid to dryness, dissolving the salt in water, passing the solution through a filter, and after having evaporated it to dryness, heating it to expel the muriate of ammonia, upon which the pure chloride of sodium remained. In some cases the quantity of chlorium in the ashes was ascertained by nitrate of silver.

The portion of the ashes which was insoluble in water was dissolved in muriatic acid, which left the sand undissolved upon which the solution was diluted, and precipitated by ammonia. This precipitate is mentioned in the tabular view as phosphate of lime, which composed the greater part of it; though it contained, in many instances, some alumina and the oxides of iron and manganese. The presence of phosphoric acid was ascertained by dissolving the precipitate in muriatic acid, adding alcohol and sulphuric acid, by which sulphate of lime was precipitated; the remaining alcoholic solution was mixed with an excess of ammonia, upon which an alkaline solution of chloride of magnesia and muriate of ammonia precipitated ammonio-phosphate of magnesium.

The ashes of all the plants of the Fucus tribe which I have analysed contain phosphate of lime. The lime and magnesia which had been in the insoluble part of the ashes was separated in the usual way. The following tabular view gives the constituent parts of the ashes of the different fucoidal plants which I have analysed. The carbonic acid of the ashes combined with lime is not stated. With regard to the silica, it is mentioned in some instances as sand, which of course had been mechanically adhering to the plant, in other instances it was in a state which made it probable, that it belonged to the constitution of the plant, which however is not quite proved. The great quantity of oxide of manganese, I may observe, in the ashes of *Padina pavonia*, is curious and doubtful; because I have not yet had an opportunity of repeating my analysis satisfactorily to determine this point.

Name.	Native place.	Classification.	Per cent. of the dried plant.								
			Total weight of ashes.	Sulphuric acid.	Chlorium.	Phosphate of lime, &c.	Lime.	Magnesia.	Potash.	Soda.	
1. Conferva fracta marina	Hoffmansgave, Denmark	Confervaceæ.. Confervoideæ.	not deter.	5·51	not deter.	not deter.	not deter.	not deter.	not deter.	not deter.	
2. Ulva, sp.	Havanna	Confervaceæ.. Ulvaceæ.........	......	3·87	......	......	......	......	not deter.		
3. Caulerpa, sp..........	Vera Cruz......................	Confervaceæ.. Siphoneæ	......	5·06	......	......	......	......	not deter.		
4. Laminaria latifolia	Hoffmansgave..............	Phyceæ .... Halyserideæ...	13·62	1·45	2·41	1·47	0·95	0·78	2·68	1·66	0·08 silica.
5. Laminaria digitata	Heligoland	Phyceæ .... Halyserideæ...	not deter.	5·05	4·77	1·42	1·87	not deter.	4·24	5·48	0·11 silica.
6. Ecklonia buccinalis	Cape of Good Hope	Phyceæ .... Halyserideæ...	14·27	1·89	0·13	0·78	2·76	0·73	2·67	2·39	0·48 silica.
7. Padina pavonia ...	West Indies..................	Phyceæ .... Halyserideæ...	34·75	4·46	not deter.	3·93	23·54	not deter.	not deter.	not deter.	8·19 oxide of manganese??
8. Durvilæa utilis	Chile	Phyceæ .... Fucaceæ	not deter.	4·04	3·85	0·91	2·51	0·17	2·46	5·62	
9. Fucus vesiculosus	Taarbek, Danish shores of the Sound...	Phyceæ .... Fucaceæ	......	2·86	0·23	1·05	2·35	1·19	0·98	1·05	1·20 silica.
10.	Greenland	Phyceæ .... Fucaceæ	16·22	2·06	2·30	1·49	0·49	1·10	2·64	5·22	
11. Halidrys siliquosa .	Hoffmansgave..............	Phyceæ .... Fucaceæ	15·65	3·44	2·84	not deter.	not deter.	not deter.	not deter.	not deter.	
12. Sargassum vulgare	Campechebank	Phyceæ......... Fucaceæ	22·58	3·61	4·28	0·81	4·03	1·09	5·00	5·82	
13. ...... cacciferum	Atlantic Ocean	Phyceæ .... Fucaceæ	11·62	2·22	not deter.	0·69	5·38	0·68	0·09	0·81	0·19 silica.
14. Furcellaria fastigiata	Kattegat	Florideæ .... Cryptonemeæ.	18·92	5·85	......	0·71	1·08	1·98	3·83	4·44	0·04 oxide of manganese.
15. Chondrus crispus. .	Kattegat	Florideæ .... Cryptonemeæ.	20·61	8·50	......	0·15	1·41	2·34	3·57	3·86	
16. Chondrus plicatus..	Hoffmansgave..............	Florideæ .... Cryptonemeæ.	11·23	1·61	1·20	0·80	1·02	0·70	0·76	2·25	2·77 sand.
17. Iridæa edulis	Hesselœ .... Kattegat	Florideæ .... Cryptonemeæ.	9·86	1·28	0·05	1·18	0·52	not deter.	1·19	0·86	
18. Polysiphonia elongata β denudata .	Hoffmansgave............	Florideæ .... Rhodomeleæ..	17·10	4·63	1·34	0·48	0·47	2·32	3·43	2·02	0·48 silica.
19. Delesseria sanguinea	Kattegat	Florideæ .... Delessericæ ...	13·17	5·13	not deter.	0·49	0·29	0·75	1·73	2·69	1·56 sand and silica.

It appears from these analyses, that the fucoidal plants principally separate sulphuric acid from the sea-water; the quantity of it is always very large, and never less than 1·28 per cent. of the weight of the whole dried plant. In one plant it amounted to 8·50 per cent., a quantity which is quite enormous considering the vast masses of fucoidal plants which grow in the sea; and I think that on an average we may take four per cent. of sulphuric acid in the dry sea-weed; for the mean of nineteen analyses gave 3·82 per cent. This acid is combined with potash, soda and lime, and would, after the decay of the plant, again be dissolved in the water of the ocean, were it not for an action which I shall afterwards describe.

Next to sulphuric acid the potash is the most interesting of the constituent parts of the ashes of Fucus. It occurs in a very small quantity in sea-water, and certainly constitutes a great portion of the Fucus tribe, which on an average contains two and a half per cent. of the dried plant, the mean quantity found in fourteen analyses being 2·52 per cent.

Next to the potash, the magnesia deserves the attention of the reader. On an average there is about one per cent. of the weight of the dried plant present in the ashes, a quantity which exceeds that of the lime, and may still exceed it more than appears from the tabular view, because no inconsiderable quantity of lime depends upon the numerous small shells and corals which adhere to the sea-weeds. In fact it might be doubted, whether any lime at all, in form of carbonate of lime, or such salts of lime whose acid by combustion forms carbonates, exists in the plants of the Fucus tribe, and whether all the lime belonging to the constitution of these plants is not combined with sulphuric or phosphoric acid. Magnesia occurs in great quantities in sea-water; the animals of shells and corals seem to have no attraction whatever for this substance, while the causes that bring it into the ocean are constantly acting, and thus its quantity might go on increasing. The fucoidal plants, however, absorb some portion of this vast quantity of magnesia and deposit it in the beds, which contain the solid substances of the sea-weeds, as far as they are insoluble in water.

Phosphoric acid always occurs in the ashes of sea-weeds and is probably always combined with lime.

I must still mention chlorium among the substances that occur in the Fucus, but its quantity is very variable, and there is no doubt that some of these plants (at least at certain seasons) contain no chlorium; and where only small traces of this substance have been found, as in the *Ecklonia buccinalis*, *Iridæa edulis*, and *Delesseria sanguinea*, they derive it from the salts of sea-water still adhering to the dried plants. On the other hand, it is highly probable, that the quantities of chlorium which are found in some instances are not accidentally present, and that chlorium probably combined with sodium plays (at certain seasons) a considerable part in the life of the fucoidal plants, while it may disappear at others; for potash occurs in considerable quantities in the potatoe while it is flowering, but diminishes afterwards.

A specimen of *Fucus vesiculosus*, taken in August 1844 in the Sound, washed and dried, left when heated in a close vessel 28·88 per cent. charcoal, which again left 13·33 per cent. ashes; the quantity of real charcoal thus being 15·55 per cent.

This chemical constitution of the ashes of the Fucus tribe explains several great phænomena in the general life of nature. It is now very little doubted that the original fertility of the soil, and even partially that which has been occasioned by manure, depend upon the mineral substances which play either a permanent or a transitory part in the life of the plants, and among such, sulphuric acid, phosphoric acid and potash, are those which, occurring in the least quantity in the soil, are notwithstanding absolutely necessary for the growth of most of our cultivated plants. All these substances are constantly washed out of the soil, and at last carried into the ocean, whose plants again attract them; and if the farmer that lives near the sea-shore transports the sea-weeds as a manure for his fields, he thereby gives back to the land those substances which rain has washed out of them.

It is well known that innumerable small crustacea, principally of the family of the Amphipoda, live upon the Fuci of our shores, and hide themselves in millions in the half-rotten heaps of those plants which the sea has thrown up. They derive from this food phosphoric and sulphuric acid, lime and magnesia; and the ashes of the shell of the shrimp consist, according to my analysis, of sulphate of lime, phosphate of lime, and phosphate of magnesia, with *so little carbonate of lime*, that it seems merely to belong to small shells adhering to the shrimps. It is well known that, directly or indirectly, the smaller crustacea constitute the principal food of fishes and cetaceous animals, and thus the phosphate of lime in the bones of the larger marine animals is originally derived from the sea-weeds; and also in the ocean the phosphoric acid of inorganic nature is, by means of plants, carried over to animals.

The spontaneous decomposition of the fucoidal plants, and principally of *Fucus vesiculosus*, is the following: after having during some days been exposed to the action of heat and water, a fermentation begins, in which a great quantity of carbonic acid is produced, and also a volatile substance which seems not to differ from the common spirit of wine; thus a complete vinous fermentation takes place. When that has ceased, the whole mass begins to rot, and a very complicated action commences, by which the sulphates are changed into sulphurets. M. Bischof of Bonn showed, many years ago, that this effect takes place whenever the soluble sulphates come into contact with organic substances exposed to putrid fermentation; and whoever has observed the masses of sea-weed left on the shore, will likewise have observed the smell of sulphuretted hydrogen disengaged from the alkaline sulphurets by the carbonic acid of the decomposing sea-weed and the atmospheric air. In the neighbourhood of Copenhagen, the disengagement of sulphuretted hydrogen from sea-weed is sometimes so strong, that the silver at the country places near the shore is constantly blackened by the effect of that gas.

If the sea-weeds in this state of decomposition come into contact with oxide of iron, another change takes place, and the sulphur combines by double decomposition with the iron and forms pyrites, while the oxygen combines with the potassium, sodium and calcium. This decomposition is beautifully shown on the western shore of the island of Bornholm in the Baltic, where a ferruginous spring from the lower oolite flows into the sea in a small beach, where a great quantity of *Fucus vesiculosus* is always thrown on shore. All the rolled stones at the bottom of the sea are covered with a beautiful yellow metallic coating of iron pyrites, which keeps unaltered so long as it is covered by the sea, but which on being exposed to the air weathers to sulphate of iron. It is evident that this effect is produced in the present period, since rolled pieces of bricks have even the same coating, where a ferruginous spring which flows out of a borehole has hardly existed more than fifty years. The same effect takes place if a solution of sulphuret of potash is mixed with ferruginous clay and left for some time in a close vessel; the clay assumes a black colour, and after it has been washed with water, diluted muriatic acid disengages sulphuretted hydrogen and dissolves protoxide of iron. Thus it follows, that wherever putrifying sea-weeds come in contact with ferruginous clay, iron pyrites must be formed, which penetrates the clay, and on weathering first forms sulphate of iron, and if no lime be present, will ultimately, by a new decomposition, change into sulphate of alumina. If, on the contrary, carbonate of lime acts upon the sulphate of iron, gypsum will of course be produced.

The potash which has been formed by the decomposition of the sulphuret of potassium acts upon the clay (silicate of alumina) and forms with it an insoluble combination, which probably also contains water. To ascertain this fact, which appears to me of high importance in the explanation of geological phænomena, I have several times exposed ferruginous clay to the action of a solution of sulphuret of potash with the following result:—

39·043 grains, English weight, of ferruginous clay from the tertiary formation of Stowerhoved in the island of Fyen, were analysed by means of fluoric acid, and gave 0·184 grain chloride of potassium = 0·47 per cent. chloride of potassium = 0·30 per cent. of potash.

41·957 grains of the same clay, which for some days had been exposed to the action of a solution of sulphuret of potassium, gave, by being treated with fluoric acid, &c., 0·930 grain = 2·22 per cent. of chloride of potassium = 1·42 per cent. of potash.

61·653 grains of the same clay, which likewise had been exposed to the action of a solution of sulphuret of potassium, gave 1·719 grain = 2·79 per cent. of chloride of potassium = 1·76 per cent. of potash.

The objection might be made that this potash was part of the solution which had not been properly washed out of the clay. This however is not the case, because when the clay had been washed on the filter until hardly any trace of soluble substance was left after the washing, water was evaporated, was taken from the filter, mixed up with a great quantity of water, and again collected on a new filter. It could not be avoided that the sulphuret of iron was oxidized during this long process of washing, and that the black colour of the clay slowly changed into yellowish-red. But afterwards, when the clay was tested, it contained a very small quantity only of sulphuric acid, and an action seems to have taken place between the sulphate of iron and the potash combined with the clay, by which sulphate of potash was formed, which being soluble in water of course must diminish the quantity of potash combined with clay. In one instance I succeeded in washing the clay so quickly, that no observable oxidation took place, but unfortunately it had not been weighed beforehand, and thus although the quantity of potash seemed to be considerably greater than in the other experiments, it cannot be used as an argument. Is is highly probable that by a longer action between the ferruginous clay and the sulphuret of potash, a larger quantity of potash will be combined with the clay; but at all events these experiments show, that whenever sea-weeds in the last state of decomposition act upon ferruginous clay, iron pyrites is formed and a quantity of potash is combined with the clay into a compound which is insoluble in water.

Since all the analysed species of the Fucus tribe, belonging to the most different countries, from Greenland to the Equator and the Cape of Good Hope, and to the different families, contained considerable quantities of sulphuric acid and potash, they all must have the effect described, whenever the other circumstances occur; and we may fairly infer, that even the fucoidal plants of the earlier periods of the world would produce similar changes in the clay of the sea.

The Silurian strata of the Scandinavian peninsula and the island of Bornholm contain in their oldest parts large beds of aluminous slate, which is used in a great number of manufactories for making alum, and this alumnious slate has the great advantage over those slates of the carboniferous system of Germany and a part of France, that it contains the sufficient quantity of potash which is required to make alum. According to my analysis this alum slate from Bornholm and from the church of Opsloe near Christiania, contains the following constituent parts:—

	Bornholm.		Opsloe.
Silica	59·86		65·44
Alumina	15·89		14·87
Lime	0·99		0·15
Magnesia	1·68		1·34
Potash with a small quantity of soda	3·72		4·59
		Soda	0·48
Sulphur	0·82		1·25
Iron	0·50		1·05
Carbon	8·65	Oxide of iron	0·75
Water	6·90		
			89·92
	99·01		

Oxygen, Azote, Phosphoric acid } quantity undetermined.

Carbon, Water, Oxygen, Azote, Phosphoric acid } undetermined.

In comparing these two analyses, the close resemblance to each other is certainly very interesting, in showing that during this formation the same causes have been acting at the same time all over those parts of Scandinavia where this formation is now found. The only real difference consists in the quantity of silica, of which about 6 per cent. more are found in the Opsloe slate than in that of Bornholm: all the other constituent parts come as close to each other as they do, even in simple crystallized minerals from different parts of the world. Those slates which I have analysed did not contain any pyrites in particles that are visible to the naked eye. But in all places where alum slate occurs, there also occur peculiar beds, which contain a much greater quantity of pyrites connected with fossils that have not yet been determined, but which seem to belong to the vegetable kingdom and may belong to some species of fucoidal plants. The slate of one of these beds of the island of Bornholm from the same quarry where the other slate had been taken, contained the following quantities of sulphur, iron and silica, the only substances that were determined:—

Sulphur	3·72
Silica	53·88
Oxide of iron	6·80

In Bornholm and in Scania (the southernmost part of Sweden) this slate contains a great number of impressions of a fucoidal plant, of which Liebmann, at my request, has been so kind to give the following description:—

Ceramites Hisingeri. Alga cæspitosa filamentosa ramosissima. Fila e basi communi (radice) radiantia ad setam equinam crassa, fastigiato-ramosa dichotoma; substantia interna venis duabus (siphoniis) creberrime genuflexis et invicem spiraliter tortis (in modum generum Polysiphoniæ, Callithamnii, Griffithsiæ, Ceramii) percursa.

According to Prof. Keilhau, Prof Boek and M. Esmark, the same Ceramites occurs frequently in the aluminous Silurian slate of southern Norway. Recently M. Hisinger has figured an imperfect specimen of it from Berg in the province of Ostergothland in Sweden; thus this Fucus appears to be characteristic of the alum slate of Scandinavia; and I can scarcely doubt that the most characteristic properties of the alum slate as depending upon its carbon, its sulphur and its potash, are derived from the great quantity of sea-weed which has been mixed up with the clay, and whose carbonaceous matter so affects the whole rock, that the slate is used as fuel for boiling the aluminous liquor, and burning lime, and in some parts of the province of Westergothland in Sweden even small courses of true coal occur. There can hardly remain any doubt that this coal is derived from sea-weeds of which the fossil parts have been found, for not the slightest trace of land plants has ever been discovered*.

In most parts of Sweden, principally in Westergothland, the aluminous slate, which rests upon a quartzose sandstone, is separated from the upper slates, which are not aluminous, by a large bed of limestone, which contains *Asaphus expansus*, *Illænus crassicauda*, and numerous Orthoceratites. The aluminous slate contains a vast number of small Trilobites, which are peculiar to it, and might appear at first to prove it a peculiar formation deposited at a time when other animals lived in the sea than those which occur in the overlying limestone. In Scania and in Bornholm the aluminous slate and the bed of limestone with *Asaphus expansus* are merely subordinate beds in the large formation of lower Silurian slates, and of course contemporaneous with them. Notwithstanding, the aluminous slate contains a vast number of the same small Trilobites, and the limestone the same *Asaphus expansus* which is found in the peculiar beds of Westergothland, thus proving that all these animals have lived at the same time. If we compare the great number of small crustacea which now live in the sea-weed thrown upon our shores, it appears to me highly probable, that the great number of small Trilobites and Agnosti which are found in the aluminous slate are the representatives of those of our crustaceans which live upon sea-weed, and that the difference in the fossils of the aluminous slate, the limestone bed and some of the beds of the clay slate, does not depend upon the difference of time in their formation, but arises from a difference of food in various localities for these animals.

There is still another difference between the alum slate and the surrounding clay slate; while the last contains more or less carbonate of lime dispersed through it, the alum slate contains a very small quantity of it. In fact, if alum slate contained lime in any considerable quantity, it would be quite useless in the manufactory of alum, because all the sulphuric acid would combine with lime instead of alumina, and form gypsum instead of alum. If however we consider the whole mass of alum slate, lime is not wanting; the difference consists only in the circumstance, that the carbonate of lime of the alum slate is collected into large balls or concretions penetrated by bituminous substances, and on that account black and fetid on being rubbed, while it is not so if collected in the common clay slate of these regions. It is evident that there must have been some cause or other by which the carbonate of lime was first dis-

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* An objection might be made, that this cause would not be sufficient to account for the enormous mass of iron pyrites deposited in the alum slate, but a calculation will show that this is not the case. At the point of Kronborg near Elsingor, about 30,000 two-horse loads of sea-weed are annually thrown on shore in the months of November and December, which, calculated at 500 lbs. dry plants each, are equal to 15 millions of pounds, which at 3 per cent. sulphuric acid, would make 450,000 lbs. of sulphuric acid and 332,000 lbs. of iron pyrites; and if we then calculate every solid cubic foot of alum slate at 15 lbs. and the alum slate on an average at 2 per cent pyrites, the quantity of sea-weed annually thrown upon the shore at Kronborg would thus be sufficient to impregnate 111,000 cubic feet of alum slate with pyrites. Besides, I may mention the enormous extent of floating sea-weed in the gulph-stream between Europe and America, as more than sufficient to account for any known quantity of pyrites in sedimentary deposits.

solved and afterwards deposited again by way of crystallization; and the appearance of carbonaceous matter and of iron pyrites in the slate being, in Scandinavia at least, always connected with the collection and crystallization of carbonate of lime in large nodular masses, it appears that there must be some causal connection between all these phænomena. It is well known that carbonic acid dissolved in water has the power of dissolving carbonate of lime, and of depositing it again in a crystalline state whenever the carbonic acid gas can escape; and although geologists generally suppose the carbonic acid to be derived from the interior of the earth, yet any free carbonic acid, from whatever source it may originate, will have the same effect. I have already shown before, that the first process in the spontaneous decomposition of fucoidal plants of the present time, is the formation of a great deal of carbonic acid, and I therefore think it highly probable that the carbonic acid which accompanied the decomposition of sea-weeds, has dissolved the lime of the slightly marly clay, and collected it into large nodular masses. It appears to me that both the detailed coincidence of the phænomena observed at the present time, with the facts observed in this large and important Silurian formation, are a strong proof of the correctness of my views.

As to newer formations of beds, where fucoidal plants have had a considerable influence on the chemical composition, I name with great hesitation the lias slate of the coast of Yorkshire near Whitby. In fact I am not aware that any impressions of fucoids have been found in this extensive formation; but then it is well known, that sea-weeds retain their form under very favourable circumstances only, and that geologists generally pay very little attention to those undefined plants which are considered to be of little use in determining the age of the formation. Besides the want of fossil fucoids, the want of potash in the lias slate of Whitby seems to be a serious objection to the influence of sea-weeds on this formation; but then, although the shale does not contain a sufficient quantity of potash to make alum, yet it may contain a small quantity of it, and I am not aware of any analysis of this shale. On the other hand, the pyrites disseminated through the shale, the carbonaceous substances which it contains, and the nodular concretions of carbonate of lime similar to those of the alum slate in Scandinavia, offer no small points of analogy. We find, besides, that the sulphuric acid in the ashes of the fucoids is frequently combined with lime, as for instance in the *Fucus vesiculosus* of our shores; and the spontaneous decomposition of this plant, when acting upon ferruginous clay, would form a great deal of pyrites and a small quantity of potash, while the lime would assist in forming the nodules of impure limestone.

In the island of Bornholm the older greensand contains numerous beds of coal, and in some beds an enormous number of *Fucus intricatus*. The deposit contains no clay, and thus no potash could be retained*, but all the iron of the formation is combined with sulphur in pyrites, which seems to be owing to the same action.

Lastly, a tertiary deposit contemporaneous with the subapennine formation, contains (all over the Danish peninsula) very large beds of alum earth. This alum earth is black, contains much pyrites, and at the same time potash; the carbonate of lime in this formation is also collected in nodular masses; it is full of marine shells, but no fossil fucoids have yet been found in it.

The Silurian alum slate seems particularly well-disposed to form gneissose rocks by metamorphosis; but before I show that this really has been the case in the neighbourhood of Christiania, I must as a chemist beg leave to offer a word upon metamorphosis in general.

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* By this expression the author refers to the insoluble combination of potash with clay described in preceding paragraphs.—Ed.

Metamorphosis of rocks may be of two very different kinds.

1. It may depend upon another arrangement of the constituent parts; thus the whole mass after metamorphosis may contain the same elements in the same quantity as before; but the state of semi-fluidity has allowed the particles to combine into other minerals and to assume a crystalline form. This is the case for instance with a Pentamerus limestone near Jellebeck, near Drammen in Norway. This impure limestone contains besides carbonate of lime, some carbonate of magnesia, alumina, oxide of iron and silica. The compact carbonate of lime has assumed a granular form and has become white marble; the magnesia has lost its carbonic acid, and combined with lime and silica to form the mineral Tremolite; and the oxide of iron has combined with alumina, lime and silica, to form greenish and beautifully crystallized garnets. The small per-centage of water, some carbonic acid which was combined with magnesia and lime, and the carbonaceous substance which communicates its black colour to the original limestone, have disappeared; but the quantity of the substances thus expelled is so small, that it has very little effect upon the whole, and is merely accidental; for if the limestone had been very pure it would have passed into granular marble without loss. If any doubt still remained that any such effect could take place, the changes which some simple minerals of the highly interesting iron mines of Arendal have undergone, seem to leave no doubt concerning this action. The mineral collection of the University of Copenhagen possesses a large crystal which has completely the form of paranthine (scapolite); it is a right square prism with all the lateral angles slightly truncated. There cannot be any doubt of this crystal having once been paranthine, but not the least trace of that mineral is left. It consists of a coating of albite, and in the interior it is filled up with imperfect crystals of epidote, while pretty large holes remain between the crystals of epidote in the interior, which were probably formerly filled up with carbonate of lime which has been abstracted by the mineral dealer by means of muriatic acid. Now the green paranthine from Arendal consists, according to John, of

Alumina . . .	30·00	Oxide of manganese	1·45
Lime	10·45	Soda	2·00
Oxide of iron .	3·00	Silica	50·25

The soda, some alumina and silica would form albite; while the lime, oxide of iron, alumina and silica would form epidote. The specific gravity of the paranthine is 2·5 to 2·8, while the specific gravity of the albite is 2·68, and that of the epidote is 3·2 to 3·5. Thus it was necessary that, the new minerals having a greater specific gravity than the paranthine, a contraction must have taken place, and holes must have been left in the interior of this curious pseudomorphic crystal.

Some years ago Prof. Rose at Berlin published a paper on certain curious crystals, which, with the external form of pyroxene, combined the internal structure of hornblende, and these crystals, having been found in the Ural Mountains, were called Uralite. Crystals occur at Arendal in Norway which also have been called Uralite, but whether they are identical with those from the Ural or not, I am unable to say, since I have not seen the true Uralite from Russia. This Uralite from Arendal occurs always in the external form of pyroxene, but the solid angles are very often rounded, as if it had been in a state which very nearly approached to fusion, and the surface shows the curious appearance which is often observed in clays, as if a coating already solidified had been *drawn* in by a floating interior mass, and thus formed small folds on the surface. In the interior these crystals have very often the structure of hornblende, but together with the hornblende there always appears another mineral, which is generally brown garnet, and the crystals of this mineral frequently appear on the surface of the metamorphous crystals of pyroxene, but never protrude beyond it. Also in this case there exists a space between these different crystals filled up with carbonate of lime, which in all the Arendal minerals is the last-formed substance that fills up all the space left by the other minerals. Although hornblende and garnet are the most frequent minerals resulting from the change of the pyroxene, yet they are not the only ones that appear. In fact hornblende seems in most cases to be one of the new minerals; but garnet is now and then wanting, and instead of it magnetical iron ore, epidote, and perhaps even other minerals occur. The specimen in which the pyroxene is changed into hornblende and magnetical iron ore, is a very curious one, one half of it being covered with unaltered pyroxene having a smooth shining surface, the other halt of it is equally covered with crystals of the same size and appearance; but they are uneven and dull on the surface, and on closer examination it is easily discovered that the internal structure of hornblende may be seen in every one of the altered crystals, while at the same time a number of small grains of magnetical iron ore have spread themselves through the whole mass. The great variety in the minerals produced from the metamorphosis of the black pyroxene depends evidently upon its very variable composition and its numerous constituent parts, which, according to the laws of isomorphism, may replace each other.

It is evident that these altered crystals have not been completely melted, since the whole external form, depending upon the former state of combination, is still left. On the other hand, it is likewise evident that there must have been a kind of fluidity in the interior of these crystals, else the new-formed minerals could not have assumed their peculiar form. Considering the rounded edges and the clay-like appearance in the exterior of the altered crystals, very little doubt can remain, that the agent which produced these changes was heat, and that the whole phænomenon belongs to that class of chemical changes which philosophers call *cementation*, and by which, without a change in the external form, changes take place in the interior which depend upon another arrangement of the particles; as for instance in the alteration which glass undergoes by being changed into the porcelain of Reaumur.

I shall presently show, that the alum slate of Scandinavia, by a completely similar alteration of the different stages which easily may be traced, has been changed into gneiss, and that, if we except the carbonaceous matter, no substance has been carried away and none has been joined with the slate; so that the whole change merely consists in a different arrangement of the particles, which by way of cementation have formed new minerals that did not exist before.

2. Much more frequent are those metamorphoses where new substances have entered into combination with those that were present in the beds of sedimentary origin, and where at least other substances have sometimes been expelled or have disappeared. The metamorphosis belonging to this kind, whichis most clear and evident, is the alteration of common limestone, carbonate of lime, into anhydrate or anhydrous sulphate of lime, where the carbonic acid has been expelled by sulphuric acid, which in most instances proceeded from the interior of the earth. The greater part of the ancient Scandinavian gneiss has evidently been formed by such an action where the granite as an eruptive mass has carried vapours of potash with it, which have penetrated the surrounding and heated slates. At the first instance it may appear

inconceivable that granite being overloaded with an acid (silica, which appears in form of quartz) could give out vapours of potash, which is a base; but this depends upon the peculiar nature of silica, which at high temperatures require less base to be dissolved than at a lower heat. I am disposed to think that granite when melted is one single compound, which on cooling is alone separated into the different minerals which compose it. In the melted state it may give out much of its volatile bases, potash and soda, until a compound remains, which for that temperature will not allow any more potash to be volatilized.

If it thus is the case, that granite at a high heat may give out vapours of potash and soda, these vapours will penetrate the surrounding slates, and will form alkaline silicates, which at a sufficient heat will crystallize and combine according to the degree of temperature either to form granite or gneiss. Further off from the source of the alkaline vapours, where less potash and soda penetrate, very little felspar will be formed, the whole potash being converted into mica, which frequently is white, the iron entering into combination with alumina and silica to form garnet, which in mica slate is the representative of the felspar of the gneiss. Still further off from the granite, not even mica slate will be formed, a sufficient quantity being wanting; and the last stage of these metamorphoses will be a micaceous, hardened clay slate. Although granite generally carries vapours of potash with it, yet this is not always the case; and there exist not a few instances of protrusions of granite where the clay slate has not been converted into gneiss, but changed into other rocks with no portion or a trifling quantity only of alkaline substances.

The whole mass of intrusive rocks of the trap family which are overloaded with iron does not seem ever to have carried alkaline vapours with it, but its peculiar produce is not unfrequently boracic acid. Chemical affinities will not allow vapours of potash or soda to escape from a compound containing great quantities of the silicates of the oxides of iron, because potash and soda would combine with silica and alumina from felspar, and separate a combination of the oxides of iron in the form of magnetical iron ore. In fact, this seems to be the history of some of the most interesting layers of magnetical iron ore. It appears therefore to me of importance to distinguish in geological descriptions between *euritic* intruding rocks, which principally comprehend granite and euritic porphyry, from *trappæan* intruding rocks, comprehending the large family of greenstones, basalts, &c.; their chemical effect upon the surrounding rocks being often very different.

Having given these general views of the chemical part of metamorphosis, I will go back again to the changes which portions of the Scandinavian alum slate has undergone, where it comes into contact with certain intrusive rocks. I had the great pleasure to make these observations in company with Mr. Murchison, to whose genius and zeal we owe such very important geological works, and I shall therefore not dwell much upon the geological phænomena, but principally comment upon the chemical nature of the altered rocks.

Along the foot of Egeberg to the east of Christiania, the alum slate is not separated from the older gneiss by a bed of sandstone which generally separates the older gneiss from alum slate (Viggersund in Norway, Westergothland in Sweden, and Bornholm)*.

The first state of change which this black shining alum slate undergoes does not occur in the neighbourhood of Christiania, but is very frequent in Hadeland and some parts of Ringerige; it is black, very anthracitical, and

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* Near the church of Opsloe the alum slate has been quarried in former times for an alum manufactory, and it is there unchanged; its composition has been mentioned before.

has lost almost the whole quantity of water which it contained. It seems evident that this change has been brought about by the very numerous trappæan and euritic dykes which traverse these shales.

The second state in the change of the alum slate is into *Lydian stone*; this occurs at Bugten, near the sea-shore at the foot of the Egeberg, about a couple of English miles to the south of Christiania; it is black, hard, and traversed by numerous small veins of quartz, which seem to depend upon the protrusion of large irregular masses of greenstone.

The third stage is into a gneissose rock with a quantity of dark mica and black scales of a carbonaceous substance, which seems to be graphite. This variety Mr. Murchison also observed at Agersberg Castle, in the town of Christiania itself. It being a matter of great importance to ascertain whether this completely gneissose rock still contained carbon, I have made two experiments to convince me of this fact. I made an analysis like those for organic substances, and ascertained the quantity of carbonic acid, which gave the quantity of carbon as 1·28 per cent. Since there might, however, remain some doubt, whether a minute portion of the carbonic acid might not depend upon a small quantity of carbonate of lime that occurred in this rock, I dissolved a portion of it in a mixture of fluoric and muriatic acid, whereby a quantity of finely-divided carbon remained, which, after being dried, burnt on a red-hot piece of platina with the phænomena of burning carbon. It is thus completely proved that the black gneissose rock of Agersberg still contains a quantity of carbon. This carbonaceous gneiss is wanting at Bugten, where the series is generally more perfectly displayed.

Next to the layers of Lydian stone of Bugten a gneiss makes its appearance, consisting of dark green mica, white felspar, quartz, and a number of small cubes of iron pyrites disseminated throughout the mass. Of this most perfect gneiss (which on the place itself, however, is very closely connected with Lydian stone, and whose pyrites still show its origin from the pyritiferous alum slate) I made a complete analysis, the result of which, compared to the analysis of the alum slate of Bornholm and Opsloe, is the following; the water and carbon of the alum slate having been deducted before the per-centage was calculated:—

	1. Gneiss from Bugten.	2. Alum slate from Opsloe, after deduction of the volatile parts.	3. Alum slate from Bornholm.	4. Alum slate from Bornholm.
Silica	69·71	72·40	71·72	71·72
Alumina	13·59	16·45	19·04	
Peroxide of iron	7·77	2·26	Pyrites 1·58	Oxide of iron 9·06
Lime	0·23	0·17	1·19	
Magnesia	2·65	1·48	2·02	
Potash	3·79	5·08	4·46	
Soda	0·46	0·53	traces	
Sulphur	2·30	1·25		Sulphur 4·15
	100·68	99·62	99·87	

In analyses 1, 2 and 4, the quantity of oxygen corresponding to the quantity of sulphur which was found must be deducted, because a portion of iron is present as pyrites. In No. 4 only the quantity of silica, oxide of iron, and sulphur was determined, and their quantity given proportionally to the silica in No. 3.

If we compare these analyses, the close connexion of the rocks analysed cannot escape observation;—the same quantity of silica, magnesia, lime, potash and soda, and only a difference in the quantity of alumina, iron and sulphur, the alumina occurring in a less quantity in the gneiss, while iron and sulphur occur in a much greater quantity than in the common alum slate. But then the sulphur and iron in the alum slate are very irregularly distributed, and beds occur which are very rich in iron pyrites; the bed No. 4, which has been analysed in No. 4, containing even more sulphur than the gneiss from Bugten. The quantity of sulphur must in part depend upon the quantity of iron in the clay which had acted upon the sulphuret of potassium. The great quantity of dark green mica in the gneiss depends upon the presence of oxide of iron, besides the pyrites; and on looking at No. 4, it is the same case in this alum slate.

I could not trace any distinct boundary between this gneiss of Bugten and the large mass of gneiss which forms the principal range of the Egeberg; and near the church of Opsloe one may pursue a similar change in the nature of the rock, although the passage from the alum slate to the gneiss is not as clearly to be traced as at Bugten.

At both places these changes of the alum slate are connected with large intruding masses of greenstone which irregularly rise from below. Numerous small veins of quartz likewise pass through all the different varieties of the altered rock, from the complete gneiss to the black Lydian stone.

At the Egeberg near Opsloe, euritic dykes traverse the altered rocks, and these dykes afford a new proof of the peculiar nature of the gneiss which they pass. They have the general chemical character of the intruding euritic rocks of Scandinavia, their alkalies consisting for a great part of soda; while the newer metamorphic gneiss of Egeberg, like its parent the alum slate, contains a trace of soda only in its composition.

The *older gneiss**, like that of Bornholm, which lies *unconformably* below the lowest Silurian sandstone and alum slate, contains likewise a considerable quantity of soda in its composition.

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* *Note by Mr. Murchison.*—My friend Professor Forchhammer having entrusted this most important paper to my care, I was highly gratified to find, that on being read at York it elicited a warm encomium from Professor Liebig, so eminently qualified to form a correct judgment of its chemical value. In its very remarkable application to geology I beg to caution the reader against the adoption of the idea, that Professor Forchhammer does not make a clear geological distinction between the newer gneiss and the older. He is indeed entirely of my own opinion, which will be developed in a memoir laid before the Geological Society of London, that the old granitic gneiss of Scandinavia was formed, crystallized and penetrated by granite before the lower Silurian strata were accumulated.—R. I. M.

Report on the recent Progress and present State of Ornithology.
By H. E. STRICKLAND, *M.A., F.G.S., &c.*

Introduction.

THE object of this report is to give a sketch of the recent progress, present state, and future prospects of that branch of zoology which treats of the class of Birds. As the chief, indeed the only method by which this study can be developed into a science, consists either in describing and depicting the character and habits of this class of animals in *books*, or in preserving and arranging the objects themselves in *museums*, I shall review in succession the progress which has been made in these two departments of the subject, and shall conclude with a few remarks on the *desiderata* of ornithology.

In treating of the bibliography of ornithology, however, it is not necessary to go into much detail respecting the works of older date than about fifteen years ago. The ornithological works of the last and the earlier part of the present century are well known to most naturalists, and the reader will find ample and for the most part just criticisms respecting them in Cuvier's 'Règne Animal,' vol. iv., Temminck's 'Manuel d'Ornithologie,' Swainson's 'Classification of Birds,' and his 'Taxidermy and Bibliography,' Wood's 'Ornithologist's Text Book,' Wilson's article *Ornithology* in the 'Encyclopædia Britannica,' Rev. L. Jenyns's 'Report on Zoology,' 1834, Burmeister's article *Ornithologie* in Ersch and Gruber's 'Encyclopädie der Wissenschaften,' and other sources. I shall therefore only give such a cursory notice of some of the earlier writers on ornithology as will serve to introduce the more legitimate subject of this report.

It may perhaps surprise those who are not very conversant with the subject to be told that ornithology is in a less advanced state than many other departments of zoology. Persons who are accustomed to regard "stuffed birds" as constituting the most usual and most attractive objects of a public museum, will not readily admit that the various species of Mammalia, Fish, Insects, Mollusca, and even Infusoria, are more accurately determined and more perfectly methodized than the class of Birds. Such is however the case, and although in the last few years ornithology has certainly made a very marked progress, yet it is still considerably in the rear of its sister sciences.

This backward condition of ornithology must be attributed in great measure to the pertinacity with which its followers during many years adhered to the letter instead of to the spirit of Linnæus's writings. In this country the venerable Latham, who for half a century was regarded as the great oracle of ornithology, persisted so late as 1824 in classifying his 5000 species of birds in the same number of genera (with very few additions) as were employed by Linnæus for a fifth part of those species. The consequence was that many of the genera in Latham's last work contain each several hundred species, frequently presenting the most heterogeneous characters, and massed together without any, or with only very rude, attempts at further subdivision. Shaw's 'General Zoology' was, in a great measure, a servile copy of Latham's 'Ornithology,' and these two works formed for many years almost the only text-books on the subject. On the continent meanwhile, those who were not disciples of Linnæus, transferred their allegiance to Buffon, and often exceeded that author in their contempt for systematic arrangement and uniform nomenclature.

Cuvier, indeed, as early as 1798, had sketched out an improved classification of birds in his 'Tableau Elémentaire de l'Histoire Naturelle,' repeated with amendments in his 'Anatomie Comparée' in 1800. The main features of his arrangement correspond with that which he afterwards adopted in his 'Règne Animal.' About the same period also, Lacépède published a system, arranged on a new plan and containing the definitions of several new genera. Another outline of an improved ornithological system was published in 1806 by M. Duméril in his 'Zoologie Analytique.' But these attempts at progress seem to have been made before the scientific world was able to appreciate them, and several years elapsed before their influence was generally felt.

The logical and accurate Illiger was the next who endeavoured to introduce sounder principles into ornithology; his admirable 'Prodromus Systematis Mammalium et Avium,' published in 1811, after long years of neglect, has now become an almost indispensable handbook to the studier of Mammals and Birds. But this young reformer died at an early age, and ornithology again relapsed under the drowsy sway of the Linnæan and Buffonian schools.

The next effort in advance was made in 1817, when Cuvier, having previously arranged the Paris Museum according to his own views of the natural system, embodied the results in the 'Règne Animal.' In the ornithological portion Cuvier was anticipated by Vieillot, who having access to the galleries of the museum, is charged with having appropriated the labours of Cuvier by attaching names of his own to the groups there pointed out. Be this as it may, the 'Analyse d'une nouvelle Ornithologie Elémentaire' of Vieillot, and the ornithological portion of the 'Règne Animal' of Cuvier, contain many new generalizations based upon highly important but previously neglected structural characters, and their publication indicated a vigorous effort at transferring the subject from the domain of authority to that of observation.

Temminck, who in his 'Histoire des Pigeons et des Gallinacés,' 1813–15, had introduced several new generic groups into the Rasorial order, published in the second edition of his 'Manuel d'Ornithologie,' 1820, the outline of a general system of ornithology, containing many important additions to the arrangements of Cuvier and Vieillot.

The method of De Blainville, completed in 1822, deserves notice, from his having introduced as a new element of classification the structure of the sternum and of the bones connected with it. The distinctive characters thus deduced are now generally admitted as forming valuable auxiliaries in the search after a natural arrangement.

The improved methods of classification, thus originated on the continent, made a gradual but slow progress into this country. Dr. Leach seems to have been the first British naturalist who duly appreciated the labours of Cuvier, and in the concluding volumes of Shaw's 'Zoology,' published under his superintendence, the new generic groups of the continental authors were successively introduced, and engrafted upon the stock of Linnæus and Latham. Dr. Horsfield also entered thoroughly into the spirit of the reformers of zoology, and in his valuable memoir on the Birds of Java in the Linnæan Transactions, vol. xiii., he adopted the arrangements of Cuvier and of Leach, with many excellent additions of his own. Dr. Fleming's 'Philosophy of Zoology,' 1822, also contributed to render the naturalists of Britain familiar with the improved systems of the Cuvierian school.

The late Mr. N. A. Vigors gave, in 1823, a great impulse to the study of ornithology by his elaborate memoir in the Linnæan Transactions, vol. xiv., on 'The Natural Affinities that connect the Orders and Families of Birds.' This treatise abounds with original observations and philosophical inferences, but unfortunately they are applied in support of a theory which the most careful inductions and the most unprejudiced reasonings of subsequent naturalists have shown to have no claim to our adoption as a general law. Without entering further upon the *vexata quæstio* of the "Quinary System" than as regards its application to ornithology, I may remark that if we can show that this supposed universal principle fails in its application to any one department of the animal kingdom, it loses its character of universality, and a presumption is raised against its truth even as a *special* or *local* law. The quinary system in fact includes several distinct propositions, the truth of any one of which does not imply that of the remainder. First, it is laid down that all natural groups, if placed in the order of their affinities, assume a circular figure; secondly, that these circles are each subdivided into *five* smaller circles; thirdly, that two of these are *normal*, and the remaining three *aberrant*; and fourthly, that the members of any one circle represent analogically the corresponding members of all other circles. I shall have occasion to recur to these points in speaking of Mr. Swainson's writings, and at present will merely remark, that the application by Mr. Vigors of these novel and singular doctrines to the class of birds contributed in no small degree to the advancement of ornithological science; for however erroneous a theory may be, yet the researches which are entered upon with a view to its support or refutation invariably advance the cause of truth. Alchemy was the parent of chemistry, astrology of astronomy, and quinarianism has at least been one of the foster-parents of philosophical zoology. Another debt of gratitude which we owe to the quinarians is the broad and marked distinction which they were the first to draw between AFFINITY and ANALOGY—between agreements in *essence*, and agreements in *function* only and not in essence, the one constituting a *natural*, and the other an *artificial* system. And although their foregone conclusions sometimes led them to mistake the one for the other, yet by their clear definitions on the subject they enabled others to detect the errors which in such cases they could not see themselves*.

In 1824 Vieillot presented a new edition of his system, with but slight alterations, in his 'Galerie des Oiseaux,' and in the following year Latreille proposed another arrangement, which however differs very little from that of Cuvier as finally left by him in the second edition of his 'Règne Animal,' 1829. The celebrity of its author caused the latter work to be speedily

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* The distinction between affinity and analogy is as yet but imperfectly established on the continent, or at least the terminology employed is very vague. French writers continually use the term *analogie* to express what we call *affinity*, a defect in their scientific language which they might easily remedy by making use of the word "*affinité*," and by restricting *analogie* to its true meaning. The same inaccuracy also exists in the language of geologists, British as well as foreign, when they speak of the *recent analogue* of a fossil, meaning thereby that recent species which has the strongest affinity to the extinct one. They might term it with more propriety the *recent affine*. A similar alteration would also introduce greater precision into the terminology of comparative anatomy. The parts which in different groups of animals are *essentially equivalent*, though often differing in function, are commonly termed *analogous members*, but it would be more correct to call them *affine members*, and to restrict the term *analogous* to those organs which resemble in function *without being essentially equivalent*. Thus the *tooth* of Monodon, the *nose-horn* of Rhinoceros, the *intermaxillaries* of Xiphias, and even the *rostrum* of a Roman galley, all perform a similar function, and are therefore *analogous* organs, but the relation between the weapon of offence in Monodon and the masticatory teeth of other Mammalia is an agreement in essence but not in function, and is therefore not an *analogy* but a real *affinity*. There is yet a third kind of relation between organic beings which does not deserve the name of *analogy*, but which may be simply called *resemblance*, consisting of a mere correspondence in form, but not in function or essence, such as the *resemblance* between *Murex haustellum* and a Woodcock's head, between *Ophrys apifera* and a Bee, &c., a relation which is in every sense *accidental*, though the advocates of the quinary theory have often regarded it as a true analogy.

translated into other languages, and it soon became the text-book for classification in most of the museums of Europe. The 'Règne Animal' will ever remain a monument of the industry of Cuvier and of his extraordinary powers of generalization, but it would be vain to expect that all parts of so vast an undertaking should be equally perfect, and it is therefore no matter for surprise that the class of birds, which do not seem to have been a favourite branch of Cuvier's studies, should present many defects in their arrangement. Certain it is that, not to mention many proofs of haste in the citation of species and of authors, the series of affinities is in this work often rudely broken or arbitrarily united. In his arrangement of birds Cuvier seems to have too closely followed the old authors, in adopting an isolated character as the basis of his classification, a practice which inevitably leads to arbitrary and artificial arrangements. He places, for example, the *Tanagers*, *Philedons*, and *Graculæ* in the midst of the *Dentirostres*, *Dacnis*, *Coracias* and *Paradisea* among the *Conirostres*, *Sitta* and *Tichodroma* among the *Tenuirostres*, *Furnarius* in *Nectarinia*, &c. Many of these defects were pointed out by Prince C. L. Bonaparte in an admirable critique published at Bologna in 1830, entitled 'Osservazioni sulla seconda edizione del Regno Animale,' and which is an indispensable appendage to Cuvier's work. Another valuable accompaniment to the 'Règne Animal' is the series of plates published by Guérin under the title of 'Iconographie du Règne Animal de Cuvier.'

This slight preliminary sketch of the progress of ornithological classification has now conducted us to a period when it becomes necessary to enter into greater detail.

I propose, as far as I am able, to notice all the more important ornithological works which have been published since 1830, and which have contributed to bring the subject to its present state, not indeed of *perfection*, but what is more interesting to those engaged in it, of *progress*. I must however regret, that from the difficulties of obtaining access to many rare continental publications, especially to the almost innumerable annals of scientific societies, this attempt at a general survey of the subject will unavoidably be somewhat incomplete. I shall of course pass over such works as are devoid of *scientific* merit, as well as those mere compilations, which from their want of any new or original matter tend only to diffuse and not to advance the science.

In entering on so large a field it becomes necessary to subdivide the subject, which may be treated of under seven heads, viz.—1. General systematic works. 2. Works descriptive of the Ornithology of particular regions. 3. Monographs of particular groups. 4. Miscellaneous descriptions of species. 5. Pictorial Art as applied to Ornithology. 6. The Anatomy and Physiology of Birds, and 7. Fossil Ornithology.

1. *General Systematic Works.*

Lesson, who in 1828 had published a useful little 'Manuel d'Ornithologie,' based chiefly upon Cuvier's classification, brought out in 1831 a more extended work, entitled 'Traité d'Ornithologie.' This book, which professes to enumerate all the species of birds in the Paris Museum, is upon the whole a very unsatisfactory performance, presenting all the marks of great haste and consequent inattention. Many professed new species are named without being described, others are described without being scientifically named; no measurements are given, and the descriptions are often so brief and obscure, that it is impossible to determine a species by their means. The work, nevertheless, contains the definitions of many new generic groups which are now adopted into our systems, and M. Lesson is therefore entitled to the credit of these original generalizations. The classification followed in this work is very complex, and in some of its portions very artificial, the genera being arrived at through a numerous and irregular series of successive subdivisions, founded in many cases upon arbitrary and isolated characters. Perhaps the most valuable portions of the work are the generic definitions, which are worked out with greater care than the specific descriptions.

Professor Eichwald gave a synopsis of the class of birds with brief descriptions of the Russian species in his 'Zoologia Specialis,' Wilna, 1831. Prefixed to it is a good general *resumé* of the characters, external and internal, of the ornithic class.

The arrangement of birds proposed by Wagler (Systema Amphibiorum) and by Nitzsch (Pterylographia) have not yet fallen under my inspection.

In 1831 the Prince C. L. Bonaparte published his 'Saggio di una Distribuzione Metodica degli Animali Vertebrati,' exhibiting a system of ornithology, of which he had previously given a sketch in the 'Annals of the Lyceum of New York,' vol. ii. 1828. As this arrangement seems in its main features to approach more nearly to the system of nature than any contemporary method, it will be worth while to enter into some detail respecting it. The author divides the class of birds in the first instance into *two* great groups or subclasses, *Insessores* or perchers, and *Grallatores* or walkers, the first including the orders *Accipitres* and *Passeres*, and the second the *Gallinæ*, *Grallæ*, and *Anseres*. Most other zoologists, from the time of Linnæus to the present day, unconsciously prejudiced by the size, rapacious habits and celebrity of the birds of prey, have attached too much importance to their characters, and have made them into one of the primary divisions of the class *Aves*. But on an unbiassed estimate of their characters it will appear that the *Accipitres* form merely a division of the great group of Perchers, agreeing with them in all essential points of organization, and not differing more than some of the subdivisions of the perchers do from each other. It was therefore a justifiable act to lower the *Accipitres* from the lofty place which they had long occupied, and to subordinate them to the *Insessores*. I even think that the learned author might have gone a step further, by making his subclass *Insessores* to consist of *one* order, *Passeres* only, while the *Accipitres* would stand on a level with his *Scansores* and *Ambulatores*, as a tribe or subdivision of *Passeres*.

The primary division of all birds into *perchers* and *walkers*, though professedly based on the position and development of so unimportant an organ as the hind-toe, and therefore liable at first sight to be termed arbitrary and artificial, is yet confirmed by so many other important and coextensive characters to which the structure of the hind-toe serves as an external indication, that we cannot doubt of this arrangement being conformable to nature. No person acquainted with the difficulty of defining the larger groups of zoology, will, of course, expect logical exactness in the application of these or of any other set of characters to the orders of ornithology. But allowing for such exceptions as occur in all zoological generalizations, it is certain that by this arrangement two great groups of birds are pointed out, the one arboreal, with perching feet, monogamous, constructing elaborate nests, and rearing a blind, naked, and helpless offspring; while the others are terrestrial, with ambulatory feet, frequently polygamous, displaying no skill in the form of their nests, and producing young which are clothed and able to see and to run as soon as hatched.

The classification of Vertebrata, which Prince C. L. Bonaparte sketched out in the above work, is further developed in a paper which he communicated to the Linnæan Society (Transactions, vol. xviii.). The diagnostic characters of all the families and subfamilies are here worked out with elaborate exactness, as they are also in his 'Systema Ornithologiæ,' published in the 'Annali delle Scienze Naturali di Bologna,' vols. iii. and viii. In these latter esays the author introduces several modifications, the most important of which is, that he removes the *Psittacidæ* from the other *Scansores*, and places them as a separate order at the commencement of the system, before the *Accipitres*. This arrangement, which was first proposed by Blainville, is grounded on the curvature of the beak, the presence of a cere, and the reticulation of the tarsi, which are supposed to connect the *Psittacidæ* and *Accipitres*. I must be allowed however to differ from this opinion, as the Parrots appear to me to be much more closely allied to the other *Scansores*, with which they are usually classed. In the nature of their food, the prevailing red and green colours of the plumage, the structure of the tongue in some genera (*Trichoglossus*), and of the beak in others (*Nestor*, &c.), they seem really allied (though somewhat remotely) to the *Rhamphastidæ*, and through them to the *Bucconidæ* and *Picidæ*.

An arrangement of the chief families and genera of birds, with definitions of their distinctive characters, will be found in the 'Elémens de Zoologie,' by M. Milne Edwards, 1834 (2nd ed. 1837), and in similar introductory works by Oken and Goldfuss.

Professor Sundevall published a new classification of birds in the 'Kongl. Vetensk. Acad. Handlingar,' Stockholm, 1836. He divides them into two large groups, nearly corresponding with the *Insessores* and *Grallatores* of the Prince of Canino. He agrees with Mr. Swainson in attaching a real importance to the analogical representation of groups, but appears not to insist on their numerical uniformity.

Mr. Swainson had, in 1831, given a sketch of his ornithological system in Dr. Richardson's 'Fauna Boreali-Americana,' but as his plan is more fully developed in the 'Classification of Birds,' forming part of Lardner's 'Cyclopædia,' published in 1836-37, we will confine our attention to the latter work. Of all the authors who have followed the quinary arrangement, Mr. Swainson has carried it to the greatest extent, having in various volumes of Lardner's 'Cyclopædia' endeavoured to apply it not only to the whole of the *Vertebrata*, but also to the *Mollusca* and *Insecta*. In speaking of Swainson as a *quinarian* author, it should be explained that he divides his groups in the first instance into *three*, but as one of these is again divided into *three*, these last, with the two undivided groups, make up the number *five* (see 'Geog. and Classif. of Animals,' p. 227). His method is therefore only a modification of the quinary theory, originally propounded by MacLeay and further developed by Vigors. In following Mr. Swainson into the details of his method, we miss the philosophical spirit and logical though not always well-founded reasoning of the two last-named authors. Firmly wedded to a theory, he is driven, in applying it to facts, to the most forced and fanciful conclusions. Compelled to show that the component parts of every group assume a *circular* figure, that they amount in the aggregate to a *definite number*, into which each of them is again subdivisible, and that there is a system of *analogical representation* between the corresponding members of every circle, which forms the sole test of its conformity to the natural arrangement, we need not wonder at the difficulties with which our author is beset; and we may certainly admire the ingenuity with which he has grappled with the Protean forms of nature, and forced them into an apparent coincidence with a predetermined system. I need not follow out the details of this Procrustean process, having already treated of it elsewhere ('Ann. Nat. Hist.' vol. vi. p. 192). With all its faults the 'Classification of Birds' is a very useful elementary work, containing numerous details of structural characters, and many just observations on the affinities of particular groups. A large number of new genera are here defined, although many which Mr. Swainson considered to be new had been anticipated by continental authors, with whose writings he was unacquainted.

Although the quinary theory, properly so called, has made but little progress beyond the British Islands, yet there is a school of zoologists in Germany whose doctrines are of a very similar character. The most eminent of these authors is Oken, who has explained his ideas on classification in several of his detached works, as well as in that valuable periodical the 'Isis,' and who communicated an outline of his theory to the Scientific Meeting at Pisa in 1839. We find in his system the same arbitrary assumption of premises, the same far-fetched and visionary notions of analogy, and the same Procrustean mode of applying them to facts, which distinguish the writings of Swainson. He professes to deduce as a conclusion, what is in fact the *à priori* assumption on which his whole theory is based,—that the animal kingdom is analogous to the anatomy of man, that is to say, that each of the organs which, when combined in due proportion, constitute the human body, are developed in a predominant degree in the several classes of animals, which represent those organs respectively. This doctrine is far toò fanciful to stand the test of common sense, but it is certainly very ingenious, and we may admit that *se non é vero é ben trovato.* The subkingdom *Radiata* he considers to represent the egg, *Mollusca* the sexual organs, *Articulata* the *viscera*, and *Vertebrata* the *essentially animal*, or *motive organs*. The subdivisions of these groups represent not only individual anatomical organs, but also each other, in a mode somewhat like that asserted by Mr. Swainson, but even more complex and ingenious, and which I have not space to develope*.

The work which most nearly represents, in Germany, the quinarian school, is the 'Classification der Säugthiere und Vögel' of Kaup, 1844. This author, like Oken, compares the Animal Kingdom to the human anatomy, but he extends the analogy of the "five senses" over every part of the system, (except his sub-kingdoms, which are three) so as to form a uniformly quinary arrangement. Thus though Kaup agrees with Swainson in adopting the number *five*, these authors are guided by different principles of analogy, the former looking to the development of the organs of sense, and the latter to points of external structure connected with habits. Hence these two quinary arrangements are very far from being coincident; Swainson for instance makes the *Raptores* one of his primary orders, while Kaup makes them a subdivision of his Water-birds! Again, Swainson makes *Corvus* the essential type of all birds, while Kaup gives the same dignified position to *Hirundo.* I need only add that Kaup's arrangement, like all *à priori* systems, is replete with conjectures and fallacies.

The fundamental error which appears to pervade these and many similar modes of classification, is the assumption of a *regularity* and, as it were,

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* The author having assumed not only that the class *Mammalia* represents the organs of sense, but that the genera of each family represent the individual senses, and these latter being commonly (though not correctly) enumerated as five, it results that, as far as the *Mammalia* are concerned, Oken's system is, like Swainson's, a *quinary* one. This coincidence of number is, however, proved to be arbitrary, and not real, by the fact that these two authors, who seem to have been wholly unacquainted with each other's writings, have in no one instance adopted the same subdivisions for their corresponding groups.

organization in that which is a mere abstraction, the System of Nature. The point at issue is this,—whether or not it formed a part of the plan of Creative Wisdom, when engaged in peopling this earth with living beings, so to organize those beings that when arranged into abstract groups conformably with their characters, they should follow any regular geometrical or numerical law. Now such a proposition appears, when tested by reason, to be improbable, and when by observation, to be untrue. The researches of the comparative anatomist universally lead to this result,—that all organized beings are examples of certain general types of structure, modified solely with reference to external circumstances, and consequently that the final purpose of each modification is to be sought for in the conditions under which each being is destined to exist. But these conditions result from the infinitely varied arrangements of unorganized matter, they are consequently devoid of any symmetry themselves, and the wild irregularity of the inorganic is thus transmitted to the organic creation. Geology has revealed to us that in all ages of the world new organic beings have been from time to time called into existence whenever the changes of the earth's surface presented a new field for the development of life, and, judging from analogy, we cannot doubt that if a new continent were hereafter raised by volcanic agency in the Southern Ocean, a new fauna and flora would be created to inhabit it, adapted to the new set of influences thus brought into action. Such a supposition appears, as far as man can presume to reason on a subject so far above him, to be more consistent with the benevolence of an all-wise Creator, than the theory which would consider the final purpose for which certain groups of organic beings were created, to be the fulfilment of a fixed geometrical or numerical law. The supporters of the latter view appear to consider that in many cases whole tribes of animals have been made, not because they were wanted to perform certain functions in the external world, but merely in order to complete the circularity of a group, to fill a gap in a numerical arrangement, or to *represent* (in other words, *imitate*) some other group in a distant part of the system. But, from what is above advanced, irregularity, and not symmetry, may be expected to characterize the natural system, and to form, like the features of a luxuriant landscape, not a defect, but an element of beauty.

If this be true, it follows that the natural system cannot be arrived at in any part of its details by prediction, but only by the process of induction. The quinarian authors have themselves suggested a method by which the affinities of organic beings may be worked out inductively, and exhibited to the mind through the medium of the eye. Having observed that the true series of affinities cannot be expressed by a straight line, and having assumed from a few instances of groups returning into themselves, that the circular arrangement was universal, they proceeded to draw these circles on paper, and thus gave the first idea of *zoological maps*. For this idea we may be grateful to them, as it indicates a process, which, if pursued inductively and not syllogistically, seems likely to be of great use in arriving at the natural classification. This process consists in taking a series of allied groups of equal rank, and placing them at various distances and positions according to a fair estimate of the amount of their respective affinities. If this be done with care and impartiality, the traces of a symmetrical arrangement, if any such existed, would soon begin to show themselves; but I am not aware that any indications of such a law are apparent in the cases in which this method has yet been used.

In 1840 I endeavoured to apply this process to the natural arrangement of birds, and exhibited to the Glasgow meeting of the Association a map of the family *Alcedinidæ* arranged upon this principle (Annals of Nat. Hist. vol. vi. p. 184). Last year I extended it to the *Insessores*, and I have brought to the present meeting a sketch of the whole class of birds exhibited by the same method. I do not of course guarantee the accuracy of any part of the arrangement in its present state, as the subject is too vast to be perfected by a single individual; but the specimen now shown may nevertheless serve to illustrate a *method* which I believe to be sound in principle, and which I would gladly see tested in other departments of organic creation*.

M. de Selys Longchamps, in the Appendix to his 'Faune Belge,' 1842, has given a sketch of an ornithological system, in which the order of succession differs little from that generally adopted. He divides the class into eleven orders, some of which, as the *Inertes*, *Chelidones*, *Alectorides*, and *Struthiones*, can hardly be said to be of equal rank with the rest. He adopts the plan proposed by Nitzsch, and followed by Keyserling and Blasius, of including with the zygodactyle *Scansores* several other groups allied to them in many points of structure, and differing from the remaining *Insessores* in having the paratarsus scutate instead of entire. It is doubtful how far this last character affords a good ground for the diagnosis of orders, and it may be objected that by adhering to this distinction we separate the *Trochilidæ* from the *Nectariniidæ*, *Phytotoma* from the *Tanagridæ*, and *Menura* from *Turdidæ*. On the other hand, this arrangement has the advantage of bringing into juxtaposition the unquestionably allied groups of *Alcedinidæ* and *Galbulidæ*, as well as the *Bucerotidæ* and *Rhamphastidæ*. The scutation of the paratarsus, therefore, may form a useful auxiliary to natural classification, although, if too rigidly adhered to, it would produce in some cases an artificial arrangement.

Few more valuable contributions have been made of late years to general ornithology than Mr. G. R. Gray's 'Genera of Birds,' which passed through two editions in 1840 and 1841. It is a list of all the generic groups which had been proposed by various authors, exemplified by reference to a *type-species* in each case, and classed according to Mr. Gray's ideas of the natural system. This work is deserving of praise on several distinct grounds. The author has exercised a rare degree of industry in collecting his materials from numerous sources difficult of access; he has applied the "law of priority" in nomenclature with great fairness and impartiality, and he has sought after a natural arrangement without any theoretical bias, and with very considerable success. Although professedly including in his list *every* genus proposed by others, yet he does not pledge himself to adopt them all, indeed he distinctly asserts that many so-called genera are too trivial for practical utility. With this limitation, the 'Genera of Birds' is by far the best manual extant for the purpose of arranging collections scientifically, and of guiding the student to more hidden and scattered sources of information.

In a compilation of such a nature as Mr. Gray's many errors of detail are unavoidable, and being sensible of the general value of the work, I ventured to point out some of them in a series of commentaries upon the two editions of the 'Genera of Birds,' which will be found in the 'Annals of Natural

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* Mr. Waterhouse communicated to the Cork meeting of the Association an arrangement of Mammalia which is on very nearly the same principle as that above referred to. His groups are all *drawn* as circular, of equal size, and placed in contact, whereas in my map of birds the groups of the same rank are of irregular form and dimensions, and are placed at greater or less distances according to the amount of their affinities. I believe, however, that Mr. Waterhouse does not lay any stress on these points of difference, and that his method is in fact reducible almost to an identity with mine. A somewhat similar mode of exhibiting affinities by diagrams has also been recently adopted by Milne Edwards (Ann. Sc. Nat. 1844), De Selys Longchamps, and others.

History,' vols. vi. vii. viii. Some critiques on the second edition were also made in the 'Revue Zoologique,' 1842, by Dr. Hartlaub, a skilful ornithologist of Bremen, who is understood to be preparing a general work on ornithology, including the distinctive characters of the species.

Mr. G. R. Gray is now engaged in issuing the 'Genera of Birds' in a much more complete and extended form, including the essential characters of the various groups, and full lists of the species and their synonyms. In this work he endeavours to reduce the various genera to an equality of rank, and is consequently compelled to reunite such genera as appear to have been separated by other authors on insufficient grounds. This task requires much judgement as well as industry, but with the resources which the galleries of the British Museum supply to Mr. Gray, he has been enabled to execute it with great success. The lithographic plates which accompany the work exhibit the essential characters of every genus, and of a large number of new or rare species, and the admirable mode in which they are executed by Mr. D. W. Mitchell confers a high degree of excellence upon this publication.

I may here be allowed to mention an undertaking of my own which has occupied the leisure of several years, but which is not yet sufficiently matured for publication,—a complete Synonymy of all known species of birds, with full references to all the works where they are figured or described. This undertaking requires considerable labour and much careful comparison of specific character, as exhibited both in nature and in books, but there is probably no department of natural history in which, from the multiplication of nominal species, and the wide dispersion of the materials, such an analysis of the whole subject is more wanted than in ornithology.

Works of reference connected with ornithology, though not strictly systematic, may be briefly mentioned here. The 'Dictionnaire des Sciences Naturelles,' the 'Dictionnaire Nouveau d'Histoire Naturelle,' the 'Encyclopédie Méthodique,' and the 'Dictionnaire Classique d'Histoire Naturelle,' were all useful works, though now more or less superseded by the progress of science. The best and most recent work 'of the kind is the 'Dictionnaire Universel d'Histoire Naturelle,' now publishing at Paris, and edited by M. C. D'Orbigny. The ornithological articles have been, till recently, written by M. de Lafresnaye, whose name is a sufficient guarantee for their accuracy. The illustrative plates are engraved with care, but in a stiff and mechanical style, and the colouring is frequently too vivid. Our own country has been less prolific in dictionaries of natural history than France, but zoological subjects are adequately treated of in more comprehensive works of reference, such as the 'Encyclopædia Britannica,' and 'Metropolitana,' and the excellent 'Penny Cyclopædia,' in which the ornithological articles are very carefully compiled. The same remark applies to the 'Allgemeine Encyclopädie,' published at Leipzig by Ersch and Gruber.

An indispensable index to ornithology, as indeed to every other branch of natural history, is the 'Nomenclator Zoologicus' of Professor Agassiz, which is a list of all the names of groups, with references to the works where they were first proposed. The portion relating to birds has undergone careful revision, and is believed to present a near approach to accuracy.

While speaking of general methods of classification I may refer to a new and unlooked-for source, from which a reflected light may in some cases be thrown upon doubtful points of ornithic affinity. The parasitic insects of the order *Anoplura* which abound on almost every species of bird, have been till recently most unduly neglected, but that able entomologist Mr. Denny has lately taken up this branch of zoology, and after publishing, with the aid of the British Association, a beautiful work on British Anoplura, is now occupied with the exotic species. He finds that these parasites constitute numerous species, and exhibit many well-marked generic forms. The remarkable fact is further deduced, that several genera of *Anoplura* frequent certain groups of birds exclusively, so that there is a sort of parallelism between the affinities of birds and those of their insect parasites. Hence we are able to infer the probable position in the natural series of an anomalous bird by investigating the structure of the almost microscopical parasites which infest its plumage, and this apparently paradoxical method has been successfully applied by Mr. Denny, who has shown that the *Anoplura* inhabiting the genus *Talegalla* are allied to those of the *Rasores*, and the parasites of *Menura* to those of the *Insessores*, an arrangement entirely confirming the views recently obtained as to the affinities of these singular birds (Ann. Nat. Hist. vol. xiii. p. 313).

2. *Ornithology of particular regions.*

Europe.—The most important work ever published on the ornithology of our own quarter of the globe is unquestionably the 'Birds of Europe' of Mr. Gould. This gigantic undertaking, consisting of more than 400 beautifully coloured plates, would have sufficed, independently of his other elaborate works, to stamp the author as a man of genius and of enterprise. Nor should it be forgotten that the talents of Mr. Gould were most ably seconded by his amiable partner, who, up to the time of her decease, executed the lithographic department of his various works. The extensive patronage which the 'Birds of Europe' received on the continent as well as in Britain, is a proof both of the excellence of the work itself and of the scientific taste of the present age.

The long-expected supplements to Temminck's 'Manuel d'Ornithologie' made their appearance in 1835-40, and bring down our knowledge of European birds to the latter date. Although the author hesitates too much in adopting the generic groups of modern science, and does not sufficiently value the law of priority in nomenclature, yet the exactness of his descriptions and the general soundness of his criticisms will long render his work a valuable hand-book of European ornithology. The series of illustrative plates, published at Paris by Werner, are a useful accompaniment to Temminck's work. The 'Hist. Nat. des Oiseaux d'Europe', now publishing by Schlegel, aided by several zoologists, and superintended by Temminck, may be regarded as an improved and enlarged edition of the 'Manuel d'Ornithologie'. The plates, by Susemihl, are of a superior order. Delarue's 'Galerie Ornithologique' forms another set of illustrations to the birds of Europe.

The 'Wirbelthiere Europa's' of Count Keyserling and Professor Blasius is a well-digested synopsis of European vertebrate zoology. The first part, with which alone I am acquainted, and which is devoted to Mammals and Birds, contains an exact catalogue of the species, with their synonyms and localities, and a statement of the diagnostic characters of the several groups from the class down to the species. These characters are stated in an antithetical mode very similar to the dichotomous method used in Fleming's 'British Animals,' a method which, when viewed in its true light, as an artificial index to specific characters, and as a means of calling attention to the presence or absence of certain structures, is probably superior to any other. Indeed when the characters employed for the subdivisions are *really essential*, and are placed in successive subordination according to a just estimate of their functional importance, as seems to be generally the case in the work before us, this method is quite compatible with a natural classification. The authors have avoided the error of adopting indiscriminately every genus which other authors have proposed, and by carefully estimating the value of their groups, reducing the less important ones to the rank of sub-genera, they have endeavoured to bring the standard of their generic groups to an approximate state of equality.

As a mere catalogue of the birds of Europe, the most full and the most accurate is that by the Prince of Canino, published in the 'Annali delle Scienze Naturali di Bologna,' 1842. It is an improved edition of that contained in the 'Geographical and Comparative List of the Birds of Europe and North America,' London, 1838, containing all the additional results at which the labours of its author have arrived. The names, synonyms, and localities of the species are given with the greatest accuracy, and by rigidly adhering to sound principles of nomenclature, the author has introduced a series of scientific names which there is reason to hope will be permanently adopted.

There remain some recent works on the ornithology of Europe, which I have not had an opportunity of consulting, such as Gloger's 'Naturgeschichte der Vögel Europas,' and others.

Britain.—Prior to 1828 the only complete hand-books of British ornithology were the valuable but somewhat obsolete 'Ornithological Dictionary' of Montagu, and the fascinating, though not always accurate, 'British Birds' of Bewick. In the above year appeared the 'British Animals' of Dr. Fleming, a work which had no small share in introducing into this country the improved systems of modern zoology. The genera adopted are for the most part those of Cuvier's 'Règne Animal,' and the specific descriptions and remarks, though brief, are in general accurate.

A somewhat similar work, the 'Manual of British Vertebrata' of the Rev. L. Jenyns, is one of the best examples of a *hand-book* that I am acquainted with, containing every fact of importance connected with each species, and being totally free from superfluous verbiage.

Of the magnificent plates to Mr. Selby's 'Illustrations of British Ornithology,' I shall speak elsewhere. The letter-press, in two volumes, 8vo, 1833, is very complete in its details, which are founded in great measure on the personal observations of the author, and the synonymy has been worked out with very great attention.

In 1836 Mr. T. C. Eyton published a 'History of the rarer British Birds.' It is intended as a supplement to the work of Bewick, containing the species which had been added to the British fauna since his time, and it is illustrated with wood-cuts, into which the artist has infused much of the spirit of that celebrated engraver.

Meyer's 'Illustrations of British Birds' are a series of coloured plates very neatly executed.

It remains to notice three other works on British ornithology, the nearly simultaneous appearance of which is an evidence of the popularity of the subject.

Professor M'Gillivray, in 1836, published an account of the 'Rapacious Birds of Great Britain,' which was followed in 1837 by his 'History of British Birds,' in 3 vols. The author, who is an active field naturalist, as well as an expert anatomist, gives very full descriptions of the external and internal structure, as well as of the habits, of the several species and groups. These are interspersed with matter of a more miscellaneous nature in the style of Audubon's 'Ornithological Biographies', which render the work an entertaining though voluminous production. The classification is novel, but cannot be regarded as successful, the terrestrial birds being classed in two large sections, one of which consists of the *Fissirostral* and *Raptorial* birds, and the other includes the remaining *Insessores*, together with the *Rasores*. The remarks on Classification and Nomenclature in the Introduction are, for the most part, sound and judicious, though the author has not always adhered to his own rules.

Professor M'Gillivray has given a condensed abstract of his larger work in two small volumes, entitled 'A Manual of British Ornithology,' 1840-42.

Sir W. Jardine's 'History of British Birds,' forming three volumes of the 'Naturalist's Library,' is a well-illustrated work, and embodies a great mass of original observations, forming a cheap and excellent manual for the student of British ornithology.

The most elegant work on British Birds recently published, is that of Mr. Yarrell. From the beauty of the engravings and of the typography, it may rank as an "*ouvrage de luxe*," while the correctness of the descriptions, and the many details of habits, geographical distribution and anatomy, render it strictly a work of science. A second edition of this work is in preparation.

The birds of Ireland are treated of by Mr. W. Thompson in an elaborate series of papers, commenced in the 'Magazine of Zoology and Botany,' and continued in the 'Annals of Natural History.' The author has collected from his own observations and from external sources, much valuable information on habits, migrations, and other subjects connected with Irish ornithology. Being the most western portion of temperate Europe, Ireland presents some interesting peculiarities in its fauna, among which may be mentioned the occasional occurrence of American terrestrial birds in that country, though the nearest point of America is 1500 miles distant. The results of Mr. Thompson's labours are incorporated in his excellent 'Report on the Fauna of Ireland,' read to the British Association in 1840, in which careful comparisons are made between the species of Ireland and of Great Britain.

The subject of British ornithology is now so nearly complete, that the works above enumerated will probably long remain unsuperseded, and we may hope that students and collectors will now extend their attention to the far more neglected department of exotic ornithology.

North and Central Continental Europe.—Many useful works on the ornithology of Northern and Central Europe were published between 1820 and 1830, by Brehm, Nilsson, Faber, Boié, Naumann, Walter and others, but as these are prior in date to the period to which I have more particularly limited this report, and as their various merits are reviewed with candour by M. Temminck, in the Introduction to his 'Manuel d'Ornithologie,' part 3, I need not enlarge upon them here.

Of the voluminous works of M. Brehm, his last, the 'Handbuch der Naturgeschichte aller Vögel Deutschlands,' 1831, is perhaps the least valuable, on account of the immense number of so-called new species which he has introduced, based upon the most trivial and inappreciable variations of size, form, or colour. This view of the subject, if carried out, would upset the whole fabric of systematic zoology, the very foundation of which is a belief in the reality, the permanence, and the distinguishableness of species. This author still continues his predilection for imaginary diagnoses in the memoirs which he publishes in the 'Isis.'

Nilsson's 'Skandinavisk Fauna,' Lund, 1835, contains a very complete, and apparently very accurate summary of the ornithology of Scandinavia, but unfortunately the Swedish language renders it a sealed book to the majority of British naturalists. The ornithology of Scandinavia has received some recent additions and corrections from a memoir by Professor Sundevall in the 'Kongl. Vetenskaps Academiens Handlingar,' 1842.

M. de Selys Longchamps, well known by several valuable monographs of European Mammals and Insects, has published the first part of his 'Faune Belge,' Liege, 1842, containing a systematic arrangement of the Vertebrata of Belgium. The specific descriptions are postponed to the sequel of the work, which is nevertheless valuable for its critical remarks on structure, habits and distribution. In the preface are some very judicious observations on the subject of systematic nomenclature, the law of priority, the limitations of species, and the still more difficult, because more arbitrary question, of the due limitation of genera. It is very satisfactory to find that the majority of European zoologists are now making considerable approaches to unanimity upon these general principles, which form the groundwork of philosophical zoology.

Dr. Gloger's 'Schlesiens Wirbelthier-Fauna,' Breslau, 1833, contains a list of the birds of Silesia, with remarks on their habits and migrations.

M. Brandt of Petersburg, has published a work entitled 'Descriptiones et Icones Animalium Rossicorum novorum,' in which several of the natatorial birds of Russia are illustrated by full descriptions and accurate figures.

France.—The ornithological portion of the 'Faune Française,' by M. Vieillot, is a useful manual, though the author has made many unnecessary changes of nomenclature. The descriptions are accompanied with figures on copper, stiffly designed, but delicately engraved.

The 'Ornithologie Provençale' of M. Roux is a respectable work on the birds of Southern France, the text being carefully drawn up, though we may regret that the author has adopted the objectionable nomenclature of Vieillot.

Italy.—The ornithological researches of Savi, Bonelli, Ranzani, Costa, and many others, prepared the way for the magnificent 'Iconografia della Fauna Italica' of the Prince of Canino, a work which, after ten years' labour, has recently been completed. It consists of elaborate descriptions and beautiful coloured plates of all the new or imperfectly elucidated Vertebrata of Italy. The birds of that country, having been previously more fully investigated than the other classes, occupy in this work the least prominent place, yet several new species are there figured, and our knowledge of others is enriched with much interesting information. The Introduction to the work contains an excellent summary of the whole subject of Italian Vertebrata. The noble and philosophical author, who pursues with steady devotion the paths of science, unallured by the manifold attractions of rank and fortune, has devoted the best part of his life to the advancement of zoological knowledge. His elaborate researches on North American ornithology, his classification of vertebrate animals, his critique on the 'Règne Animal' of Cuvier, his comparisons of the European and American faunæ, are all works of the highest value, and we may now congratulate him on the completion of this admirable digest of the vertebrate zoology of Italy. Nor let it be forgotten that he was the first to establish beyond the Alps, that great *mental*, no less than *physical* barrier, a peripatetic congress of scientific men, similar to that at which we are now assembled. This *Italian Association for the Advancement of Science* has met in the plains of Piedmont and of Lombardy; it has crossed the Appenines into the happy region of Tuscany, and it will next year pass over the Papal dominions, to diffuse the light of knowledge in the distant kingdom of Naples.

An unpretending little volume by Sig^{r} L. Benoit, entitled 'Ornitologia Siciliana,' published at Messina in 1840, contains many interesting details on the habits and migrations of the birds of Sicily. A work of greater value is the 'Faune Ornithologique de la Sicile' of M. Malherbe, Metz, 1843, in which about fifty species are added to the list of Benoit, making a total of

318. The work abounds with important observations on the geographical distribution of species, not only in Sicily, but in other parts of South Europe and North Africa. As the island of Sicily serves as a sort of *stepping-stone* between these two continents, it affords an interesting station for observing the habits of migratory species.

A similar *catalogue raisonnée* of the birds of Liguria was published at Genoa in 1840, by the Marquis Durazzo, and is entitled 'Notizie degli Uccelli Liguri.' Catalogues of the birds of the Venetian provinces have been published by Catullo, Basseggio, and Contarini, the latter of whom enumerates no less than 339 species.

A brief notice of the birds of Sardinia will be found in the 'Voyage en Sardaigne,' 2nd ed. 1839, by Count de la Marmora, in which it is announced that Professor Géné is about to publish a complete fauna of that island.

The island of Malta possesses an able ornithologist in Sig^{r} Schembri, who has published a 'Catalogo Ornitologico del Gruppo di Malta,' 1843. His other work, the 'Quadro Geografico Ornitologico,' is a highly useful volume, showing in parallel columns the ornithology of Malta, Sicily, Rome, Tuscany, Liguria, Nice, and the department of Gard. These form almost the first works on zoology ever printed in the island of Malta, and they show that, even in the most insulated localities, an active naturalist will always find abundant occupation. The author enumerates about 230 species of birds in Malta, nearly the whole of which are migratory.

Several new species of birds have been added to the fauna of the South of Europe by Dr. Ruppell, in the 'Museum Senkenbergianum,' 1837.

Greece.—But little has been done in Greece to illustrate ornithological science. The 'Expédition Scientifique de la Morée' contains a summary of sixty-six species there observed, but without adding much to our knowledge. A few new species (which however require further examination) are described by M. Lindermayer in the 'Isis,' and 'Revue Zoologique,' 1843. The most complete work on the subject is the 'Beiträge zur Ornithologie Griechenlands,' by H. von der Mühle, Leipzig, 1844, in which no less than 321 species are noticed, and are accompanied with many original observations of great value. The researches of this author have added several species to the European fauna.

The birds of the Ionian Islands and of Crete are enumerated and accompanied with some valuable remarks on their migrations and habits by Captain H. M. Drummond, 42nd R.H. in the 'Annals of Natural History,' vol. xii. p. 412.

Spain.—The ornithology of the Spanish peninsula is as yet but imperfectly known. A list of some of the birds is given in Captain Cooke's (now Widdrington) 'Tour in Spain.' (See also his 'Spain in 1843.') That gentleman was, I believe, the first discoverer of the *Pica cyanea* in Spain, a species which, if it be really identical with the *Garrulus cyaneus* of Pallas, found in Siberia and Japan, presents a most unusual instance of the existence of the same species in two remote regions, without occurring in the intervening space. M. Temminck has described several new species brought from the South of Spain by Parisian collectors, and from the proximity of that region to Africa, it is probable that further additions to the European fauna may be there made.

Of the birds of Madeira there is a brief notice by Dr. Heineken in the 'Zoological Journal,' vol. v.; and several species are described by Sir W. Jardine in Ainsworth's 'Edinburgh Journal of Natural and Geographical Science.'

The Canary Islands present a fauna more allied to that of Europe than the southern position of these islands and their proximity to the African continent would have led us to expect. The 'Histoire Naturelle des Isles Canariennes,' a splendid work lately published at Paris by MM. Webb and Berthelot, contains a list of birds, the whole of which, with the exception of a very few terrestrial species peculiar to the islands, are included in the ornithology of Europe.

Asia Minor.—The 'Proceedings of the Zoological Society' contain lists of the birds of Trebizond and Erzroum, by Messrs. Abbot, Dickson, and Ross, and of those of Smyrna by myself. There is also a short list of those obtained by Mr. C. Fellows in the 'Annals of Nat. Hist.' vol. iv. The greater part of the birds hitherto found in this country are also common to Europe, which may in part be attributed to their having been chiefly collected in the northern districts, or in my own case at Smyrna, during the winter season. An ornithologist who would visit the regions south of the Taurus during the spring, would doubtless meet with many interesting species, a foretaste of which we have in the beautiful *Halcyon smyrnensis*, discovered more than a century ago by the learned Sherard, and restored to science in 1842 by Mr. E. Forbes*.

I may here allude to the 'Catalogue of the Birds of the Caucasus' by M. Ménétries, in the 'Mémoires de l'Acad. Imp. des Sciences de St. Pétersbourg.' Although several of the supposed new species have been reduced to the rank of synonyms, yet this list supplies some valuable information on the geographical distribution of species. For the ornithology of Southern Russia, the student may also consult M. Eichwald's summary of the Caucasian and Caspian birds in the 'Nouveaux Mémoires de la Soc. Imp. des Naturalistes de Moscou,' 1842, and Demidoff's 'Voyage dans la Russie Méridionale,' the zoology of which is edited by Professor Nordmann.

Siberia.—The zoology of Northern Asia was long retarded by the delays which attended the publication of the 'Zoographia Rosso-Asiatica' of that Humboldt of the 18th century, the celebrated Pallas. This posthumous work, though printed in 1811, was not published till 1831, when it at once added to our knowledge a large number of new species. Many commentaries upon Pallas's work, and additions to his species, have been made by various authors, especially by M. Brandt, the learned and indefatigable curator of the Imperial Museum at St. Petersburg, in the 'Bulletin' of the Academy of that city, and by Nordmann in Erman's 'Reise um die Erde.' There are also some valuable 'Addenda' to the work of Pallas from the pen of Dr. Eversmann, in the 'Annals' of the distant University of Casan, and further additions have been recently contributed by that author to the Petersburg Academy. We may hope that the labours of these and other equally active Russian zoologists will soon make us fully acquainted with the natural history of Asiatic Russia.

A few of the birds of Behring's Straits are elaborately described, though indifferently figured, in Eschscholtz's 'Zoologischer Atlas,' to Kotzebue's second Voyage, Berlin, 1829.

Japan.—Drs. Von Siebold and Burger, who were attached for several years to the Dutch mission in Japan, devoted their leisure to the zoology of that little-known country, and the results have now been published by the Dutch government in a handsome work, entitled 'Fauna Japonica.' A remarkable fact established by their researches, is the great amount of coincidence between the ornithological faunæ of Japan and of Europe. In Temminck's 'Manuel d'Ornithologie,' (Introd. to part 3.), is a list of the species common to these two regions, amounting to no less than 114.

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* See Annals of Nat. Hist. vol. ix. p. 441.

British India.—It is only within a very recent period that any really original and trustworthy researches have been made into Indian ornithology. Twenty years ago the utmost that was done by the numerous British officers in that country to illustrate this science, was to collect drawings of the species which attracted their notice. These drawings were in most cases made by native artists, who, being utterly ignorant of any scientific principles, executed them in a stiff mechanical style, and neglected the more minute but often highly important characters. Such designs are useful as aids to scientific research, but ought not to usurp its place; yet from these materials the too undiscriminating Latham described and named a great number of so-called species, many of which have not yet been identified in nature. The largest collection of these drawings was made by the late General Hardwicke, a selection of which were engraved and published in 1830; but though carefully edited by Mr. J. E. Gray, the number of nominal species there introduced shows the danger of founding specific characters on the sole authority of drawings.

A better day dawned about 1830, when several British officers in India became interested in the study of scientific ornithology; and we may hope that natural history in this and all its other branches will now become a general pursuit with our countrymen in that region. The first *original* contribution to the ornithology of India in recent times was made by Major Franklin, and was speedily followed by a valuable paper from Colonel Sykes, both of which are inserted in the 'Proceedings of the Zoological Society,' 1831–32. About the same period appeared the first effort of Mrs. Gould's pencil, the 'Century of Birds from the Himalaya Mountains,' a work the plates of which at once established the fame of this admirable artist, while the scientific characters were carefully prepared by Mr. Vigors. In 1832 was also commenced that most valuable repertory of oriental knowledge, the 'Journal of the Asiatic Society of Bengal,' which is still published with regularity at Calcutta. In this journal and in others of a similar nature, as the 'Asiatic Researches,' the 'Gleanings in Science,' Corbyn's 'Indian Review,' the 'Quarterly Journal of the Calcutta Medical and Physical Society,' the 'Calcutta Journal of Natural History,' are contained the valuable but unfortunately too scattered and inaccessible zoological researches of Hodgson, Hutton, Pearson, Tickell, M'Clelland, W. Jameson and others. Mr. Hodgson, who by his residence in Nepal has been so favourably circumstanced for zoological pursuits, has long since promised to include in an entire work his scientific researches in that country, but various delays have hitherto impeded the undertaking. He has recently, with the utmost liberality, presented the whole of his precious materials to the British Museum and other public collections, and we may hope that the facilities of comparison thus afforded will enable him shortly to commence this very desirable publication.

The Indian species of *Coturnix* and *Turnix* have been described with minute exactness by Colonel Sykes in the 'Transactions of the Zoological Society,' vol. ii. This paper is of great service in clearing up the characters of these obscure and ambiguous birds, which however are still far from being thoroughly investigated.

Professor Sundevall, in his valuable Report on recent Zoological Researches, Stockholm, 1841, refers to a paper on the Birds of Calcutta in the 'Physiographisk Tidskrift,' Lund, 1837, a work which has not yet fallen into my hands.

A great impulse has recently been given to Indian zoology by the appointment of Mr. Blyth to the care of the Asiatic Society's museum at Calcutta. Most of the previous workers in that field were civil or military officers, who took up zoology as an afterthought, and as a relief from more important duties. But Mr. Blyth went to India a ready-made zoologist, who had long devoted himself to the study as a science, and was well acquainted with its literature and its principles. Of the zeal and success with which he is now bringing into order the heterogeneous materials of Indian zoology, the pages of the 'Journal of the Asiatic Society of Bengal' bear ample testimony. Besides many detached memoirs, the monthly reports which Mr. Blyth presents to the Asiatic Society contain a mass of interesting observations, and present an example which the curators of European museums would do well to imitate. By preparing complete lists of the species comprised in each successive accession to the museum, accompanied by critical remarks on the more novel or interesting specimens, previous to their being incorporated into the general collection, a number of important observations on structure, habits and geographical distribution are preserved from oblivion. In the midst of these active and useful labours Mr. Blyth retains his interest in European science, and occasionally sends communications of great value to the 'Annals of Natural History.'

While treating of Northern India I may mention the Catalogue of the Birds of Assam, by Mr. M'Clelland, in the 'Zoological Proceedings,' 1839. The author avoided the too common error of describing as new every species which was *unknown to him*, by the judicious plan of attaching provisional names and descriptions to such species, and then sending them to a highly competent naturalist in England, Dr. Horsfield, to be revised prior to publication.

The presidency of Madras can boast of a 'Journal of Literature and Science,' and of zoologists, Messrs. Jerdon and Elliott, equal in activity and scientific attainments to those of Bengal. The various memoirs of these gentlemen on the characters and habits of the birds of Southern India are of high value. Mr. Jerdon has commenced the publication of a series of 'Lithographed Drawings of Indian Birds,' illustrating many rare species in a style which does credit to the artists of India.

A few species of Indian birds have been described by Professor Jameson in the 'Memoirs of the Wernerian Society,' vol. vii., and several others are figured in Royle's 'Botany of the Himalaya Mountains,' and in the zoological part of Jacquemont's 'Voyage dans l'Inde,' Paris, 1843, the plates of which are beautifully executed. Mr. Blyth has drawn up a notice of the species received from the British officers in Tenasserim, and of the desiderata which remain to be sought for in that province. The zoological portion of M. Belanger's 'Voyage aux Indes Orientales,' 1834, contains descriptions and figures of many of the birds of Pegu and Java, among which are several novelties. Some of the species of continental India are also described in the same work. Ornithological information will also be found in Delessert's 'Souvenirs d'un Voyage dans l'Inde.

Malasia.—Under this name may be included the peninsula of Malacca and the islands of the Indian archipelago, which taken collectively form a well-marked zoological region, whose fauna, though for the most part agreeing *generically* with that of continental India, presents an almost wholly distinct series of *species*. The first contributor to the ornithology of this region was Brisson, who described, with an exactness that may serve as a model even at the present day, many new species of birds from the Philippine Islands. Sonnerat described some more species in 1776, but scarcely anything has since been added to our knowledge of the vertebrate zoology of that particular group of islands; and it is to be regretted that a considerable collection of birds recently brought thence by Mr. Cuming, were dispersed before any scientific examination of them had been made. The zoology of western Malasia was first investigated by Dr. Horsfield and Sir Stamford Raffles, the first of whom described the birds of Java and the second those of Sumatra, in the 'Linnæan Transactions,' vol. xiii. These are very valuable memoirs, though it is to be regretted that from the brevity of the specific characters some of the species are rendered difficult to recognise. A selection of Dr. Horsfield's species is however more fully described and illustrated by figures in his 'Zoological Researches in Java,' and the original specimens collected by him are preserved in the museum of the East India Company. The species of Horsfield and of Raffles were arranged into one series by Mr. Vigors in the Appendix to the 'Life of Sir Stamford Raffles.'

Between 1820 and 1830 several Dutch and German naturalists visited the Malasian Islands, and enriched the continental museums with their collections. A considerable number of the species thus obtained are figured in the 'Planches Coloriées' of M. Temminck, who however too frequently described as new the species which had been long before characterized by Horsfield and Raffles.

For two centuries past the Dutch have been famed for their love of collecting rarities, and the numerous settlements of that people in all parts of the world have tended to the gratification of this taste. It is therefore not to be wondered at that the national museum of Holland at Leyden should have become one of the richest collections of natural objects in the world; and it is gratifying to find that the information which its treasures convey is in the course of being diffused abroad. The Dutch government are now publishing a complete zoology of their foreign colonies, under the title of 'Verhandelingen over de Natuurlijke Geschiedenis der Nederlandsche overzeesche Bezittingen.' This superb work contains figures and descriptions of many new species from the remoter islands of the Malay archipelago; and it is only to be regretted that so valuable a publication should be compiled in a language with which few men of science out of Holland are acquainted.

A considerable number of ornithological specimens have recently been sent to Europe from the peninsula of Malacca, and indicate a fauna closely allied to, though often specifically distinct from, that of the adjacent islands of Java and Sumatra. Mr. Eyton has described several of these Malacca birds in the 'Proceedings of the Zoological Society,' 1839, and Mr. Blyth has characterized others which had been sent to the Calcutta Museum.

The great island of New Guinea presents features in its zoology which entitle it to be considered a distinct region from the Malasian archipelago, and connected rather with the Australian fauna. We here first meet with that extraordinary group of birds the *Paradiseidæ*, whose affinities it is impossible to assign with certainty until their anatomy and habits are better known. In this group will probably be ultimately included (as they were originally by the earlier writers) the genera *Seleucides, Ptilorhis, Epimachus, Phonygama* and *Astrapia*, which are at present arranged, from conjecture rather than induction, in many widely-separated families. These genera all agree with the *Paradiseidæ* in the very peculiar structure of their plumage, and what is of no less importance as an indication of zoological affinity, they all (with the exception of *Ptilorhis*, which is found in the adjacent Australian continent) inhabit the same island of New Guinea; and I think it not improbable that the anomalous Australian genera *Ptilonorhynchus, Calodera* and *Sericulus*, may be also referable to the *Paradiseidæ*. These questions however must be resolved by the anatomist and not by the studier of dried skins; and we may therefore regret that New Guinea has hitherto been so inaccessible to naturalists. The specimens from thence are mostly obtained in a mutilated state from the savage inhabitants, and I believe the only zoologists who have seen the Birds of Paradise in a state of nature are M. Lesson, who made some interesting observations upon them during the few days which he spent in the forests of New Guinea, ('Voyage autour du Monde de Duperrey,' and Lesson's 'Manuel d'Ornithologie,') and MM. Quoy and Gaimard, whose observations, recorded in the 'Voyage de l'Astrolabe,' 1830–33, were still more limited.

Polynesia.—The ornithology of the innumerable islands of the Pacific Ocean is as yet very imperfectly investigated. From the small size of most of these islands they cannot individually be expected to abound in terrestrial species, though in the aggregate they would doubtless furnish a considerable number, while of aquatic species an interesting harvest might be collected. At present much of our information is derived from no better source than the incomplete descriptions made by Latham of species collected during Captain Cook's voyage. Some of the birds collected by the Rev. A. Bloxam in the Sandwich Islands are described in Lord Byron's 'Voyage;' others were made known by Lichtenstein in the 'Berlin Transactions,' 1838, and the 'Zoology of the Voyage of the Sulphur,' now in course of publication, contains some further materials which have been examined and described by Mr. Gould. A few Polynesian birds are described by MM. Hombron and Jacquinot among the scientific results of the Voyage of the Astrolabe and Zelée (Ann. Sc. Nat., 1841), and several new species from the Philippine, Carolina and Marian Islands, are characterized by M. Kittlitz in the 'Mémoires de l'Acad. Imp. de St. Pétersbourg,' 1838. The recent American voyage of discovery will extend our knowledge of Polynesian zoology, and its researches will be made known by Mr. Titian Peale, who is said to have discovered among other rarities a new bird allied to the Dodo, which he proposes to name *Didunculus*.

Australia.—Shaw's 'Zoology of New Holland,' 1794, was the first work devoted to the natural history of the Australian continent, but its publication was soon discontinued. It was followed by the 'Voyages' of Phillips and White, in which many of the birds of that country were figured and described. The next additions were made by Latham, who in the second 'Supplement to his Synopsis,' 1802, described and named many species on the authority of a collection of drawings belonging to the late Mr. A. B. Lambert. These drawings however were very rude performances, and being unaccompanied by descriptions, it is no wonder that Latham was led by them into many errors of classification and synonymy. Fortunately, however, they passed at Mr. Lambert's death into the possession of the Earl of Derby, who liberally entrusted them for examination to Mr. Gould, Mr. G. R. Gray, and myself. By carefully studying these designs and comparing them with Australian specimens, we have been able to identify almost the whole of the species which Latham founded upon them, and by this process many corrections have been introduced into the synonymy of the Australian birds. (See Ann. Nat. Hist., vol. xi.)

It is to be regretted that Messrs. Vigors and Horsfield had not access to this collection of drawings when they prepared their valuable paper on Australian birds in the 'Linnæan Transactions,' vol. xv. They would there have recognised several of the species which, from having failed to identify them in the brief descriptions of Latham, they described as new. Their memoir is notwithstanding a very important contribution to Australian ornithology, especially on account of the many generic forms peculiar to that region which they defined with logical precision.

The above, together with the brief but original work of Lewin (Birds of New South Wales) and a few species described by Quoy and Gaimard in the

'Voyage de l'Uranie,' 1824, and in the 'Voyage de l'Astrolabe,' 1830, and by Lesson in the 'Voyage de la Coquille' and the 'Journal de la Navigation de la frégate Thetis,' 1837, formed the chief materials for Australian ornithology until the expedition of Mr. Gould to that country made a vast accession to our knowledge, which is embodied in his great work, the 'Birds of Australia.' Among those splendid publications of science and art which the liberality of governments have given to the world, there are few which in point of beauty or completeness are superior to this unassisted enterprise of a single individual. Regardless of expense and risk, Mr. Gould proceeded to Australia for the sole purpose of studying Nature in her native wilds, and after spending two years in traversing the forests and plains of that continent, he returned home with a valuable collection of specimens, and a still more precious one of *facts*. These he is now engaged in bringing before the public, and the many new and interesting details of natural history which his work contains indicate powers of observation and of description which will place the name of Gould in the same rank with those of Levaillant, Azara, Bewick, Wilson, and Audubon.

Of the artistic merits of this publication I shall hereafter speak, and shall refer to it at present merely as a work of science.

Among the new generic groups proposed by Mr. Gould, some, as *Pedionomus*, *Sphenostoma*, &c., possess sufficiently well-marked characters; but others, as *Donacola*, *Erythrodryas*, *Erythrogonys*, *Synœcus*, *Geophaps*, appear hardly to deserve generic separation. These so-called genera seem to be founded upon slight peculiarities of form, habit, or colouring, to which, however interesting in themselves, we ought not, I think, to attach a generic value, unless we are prepared to reduce all our other genera to the same low standard, a step which would increase the number of genera and diminish their importance to an extent that would be highly inconvenient. I may also remark that some of the birds which Mr. Gould regards as distinct *species*, appear to possess insufficient diagnostic characters. Peculiarities of climate and food will always exert a certain influence on the stature and on the intensity of colour in the same species, and so long as the proportions and the distribution of the colours remain unaltered, we should hesitate in raising the local varieties thus produced to the rank of species, unless we are ready to go the same length as M. Brehm, who by this means has trebled the number of European species. As instances of Australian birds the real specific distinctness of which appears to me doubtful, I may mention Mr. Gould's *Malurus cyaneus* and *longicaudus*, *Amytis textilis* and *striatus*, *Astur approximans* and *cruentus*, *Hylacola pyrrhopygia* and *cauta*.

Passing over these slight defects, it is certain that the facts brought for the first time to our knowledge by Mr. Gould have cleared up many doubtful questions respecting the true affinities of the anomalous forms so prevalent in Australia. Being now informed as to their habits and, in many cases, their anatomy, we are enabled to classify with certainty the once ambiguous groups *Talegalla*, *Psophodes*, *Menura*, *Falcunculus*, *Artamus* and others. In other cases, as in the genera *Ptilonorhynchus* and *Calodera*, the observed habits of the birds are even more anomalous than their structure, and rather increase than diminish the difficulty of classifying them.

Mr. Gould's work is also valuable for its critical examinations of the labours of other authors, the synonyms being for the most part carefully elaborated, and a due regard paid to the principle of priority in nomenclature. It is to be hoped that this delightful and truly original work will be hereafter republished in a more portable form, as its present costly style of illustration necessarily restricts it to a small number of readers.

This publication has tended to create a taste for natural history in the Australian colonies, which will advance the cause of morality and civilization. Among recent proofs of an improved tone of mental cultivation, I may mention the 'Tasmanian Journal of Natural Science,' commenced at Hobart Town in 1842, and which is a publication highly creditable to the southern hemisphere. One of its chief contributors is the Rev. T. J. Ewing, who is ardently devoted to science, and who has already increased our knowledge of Australian ornithology.

The tropical parts of the Australian continent exhibit, as might be expected, many new and beautiful forms. A few of these were made known in Capt. King's 'Survey of Intertropical Australia,' 1827; and the labours of Mr. Gould's collector, Mr. Gilbert, will now render the zoology of Northern and Western Australia as familiar to us as that of New South Wales.

New Zealand.—The earliest information on the ornithology of New Zealand was obtained by Forster during the voyage of Capt. Cook, of which we shall learn more particulars in Prof. Lichtenstein's forthcoming edition of Forster's MSS. A few additional species are described in the Voyage of the Coquille, 1826, and of the Astrolabe, 1830; but little was subsequently added until 1842, when Dr. Dieffenbach submitted his collection to the examination of Mr. G. R. Gray, and the result will be found in the interesting 'Travels in New Zealand' of the former gentleman. As in most oceanic islands remote from a continent, the terrestrial ornithology of New Zealand is somewhat limited; but some interesting representatives of the Australian fauna are there found, and the extraordinary structures of those anomalous birds, the *Apteryx* and *Dinornis*, atone in point of interest for the general paucity of species.

The aquatic ornithology of the Southern Ocean and its isles has been hitherto in a state of the greatest neglect and confusion; but some valuable materials for its elucidation will be supplied by the 'Voyages of the Erebus and Terror,' now in course of publication, as well as by many details introduced in Gould's 'Birds of Australia.'

Africa.—The zoology of Lower Egypt has received but few accessions since the French expedition to Egypt; but that of Nubia and Abyssinia, the foundations of which were laid by Bruce and by the present Earl of Derby, who added a valuable appendix to Salt's 'Voyage,' has been since greatly extended by the labours of Rüppell and Ehrenberg. The 'Atlas zu der Reise in Nordlichen Afrika,' and the 'Neue Wirbelthiere' of the former author, are especially valuable for the fulness and accuracy of the descriptions, and for the critical remarks with which they are accompanied. The lithographic plates, though rather coarsely executed, are sufficiently characteristic. The author has made further additions to this subject in his 'Museum Senckenbergianum.' The 'Symbolæ Physicæ' of Messrs. Hemprich and Ehrenberg, contain some accurate information on the ornithology of Abyssinia, Egypt and Syria, and we may regret that this excellent work was never completed. Besides much original matter, the authors have added many careful criticisms on the works of other authors who have written on the zoology of those countries. Some additions to Abyssinian ornithology have also been made by M. Guerin-Meneville, 'Revue Zoologique,' 1843.

No special work has been produced on the ornithology of Western Africa, except the useful little book by Swainson, which forms two volumes of Sir W. Jardine's 'Naturalist's Library.' Many new species are there defined and figured with care.

The birds procured during the late unfortunate expedition to the Niger are described in the 'Proceedings of the Zoological Society' by Mr. Fraser, who accompanied the party as naturalist.

The ornithology of South Africa is now far advanced towards completeness. The 'Oiseaux d'Afrique' of Levaillant formed an admirable groundwork for the study, and through the labours of subsequent naturalists, there is probably little more to be added to our knowledge of the subject.

The enterprising Burchell characterized several new species in his 'Travels in South Africa,' and others collected by Sir J. Alexander were described by Mr. Waterhouse in the Appendix to that traveller's 'Expedition of Discovery into the Interior of Africa,' 1838. But we owe the largest additions to South African ornithology to the energy of Dr. Andrew Smith, who, in 1832, planned and executed an expedition of discovery into the remote interior, northwards of the Cape colony. The zoological results of this expedition were first published by Dr. Smith in the 'South African Quarterly Journal,' a scientific periodical printed at Cape Town, and less known in Europe than it deserves to be. They will also be found in a pamphlet entitled, 'Report of an Expedition for Exploring Central Africa,' Cape Town, 1836. By the liberality of Her Majesty's government Dr. Smith has since been enabled to publish these new and precious materials, under the title of the 'Zoology of South Africa,' in a style and form corresponding to the 'Zoology of the Voyage of the Beagle' and of the 'Sulphur,' and forming a standard work for the library of the naturalist.

Of the birds of Madagascar but few have been described since the days of Brisson. M. I. Geoffroy St. Hilaire has made known some remarkable forms from that island in Guerin's 'Magazin de Zoologie,' 'Comptes Rendus,' 1834, and 'Ann. des Sciences Naturelles,' ser. 2, vol. ix.

North America.—The ornithology of North America (exclusive of Mexico) is now more thoroughly investigated than that of any other quarter of the globe, except Europe. The fascinating volumes of Wilson, and the invaluable continuation of his work by Prince C. L. Bonaparte, contributed to produce in the United States a great taste for natural history, and for ornithology in particular. The works of Wilson and Bonaparte have been made more accessible in this country by means of smaller editions, one of which was edited by Sir W. Jardine, and another by Prof. Jameson. A small edition has also been published in America by T. M. Brewer, Boston, 1840. Foremost among the successors of Wilson is the indefatigable Audubon, whose life has been spent in studying nature in the forest, and in depicting with pen and pencil her manifold beauties. The plates of his 'Birds of America,' more than 400 in number, are the work of an enthusiastic naturalist and a skilful artist, though the designs are sometimes rather *outré*, and their size is inconveniently gigantic. The latter evil is however remedied in a smaller edition with lithographic plates, which the author has recently published in America. The text to these plates, entitled 'Ornithological Biography,' is an amusing as well as instructive work, though written in a too inflated style. Mr. Audubon has since published a 'Synopsis of the Birds of North America,' Edinburgh, 1839, containing condensed descriptions of the genera and species, and forming a very useful manual of reference. Several of the species of *Sylvicolinæ* had been unduly multiplied by Audubon, and their synonymy has been rectified by Dr. T. M. Brewer in Silliman's 'Journal of Science,' vol. xlii.

Mr. Nuttall's 'Manual of the Ornithology of the United States,' published at Cambridge, U.S., 1832–34, is a very convenient hand-book, containing a compendium of the labours of Wilson, Bonaparte and Audubon, accompanied with many original observations on the habits of the species. The work is illustrated with woodcuts, which, though not equal to the works of Bewick, are executed in a similar style and with considerable success.

Several of the States of the American Union have adopted the truly enlightened policy of making regular scientific surveys of their respective territories. Of these the state of New York has already published several handsome volumes on other branches of natural history; but the ornithological portion is not yet issued. A list of the birds of Massachusets will be found in Prof. Hitchcock's Report on the Geology of that State. This list has been further extended by Dr. Brewer and by the Rev. W. Peabody in the 'Boston Journal of Natural History,' 1837 and 1841. The latter gentleman has given much valuable information on the manners and migrations of the species. Some popular notices of the birds of Vermont are given by Mr. Z. Thompson in his 'History of Vermont,' Burlington, 1842.

A mass of interesting observations on the zoology of the arctic portion of North America is contained in the appendices to the narratives of Ross, Parry, Franklin and Back, and in the 'Memoir on the Birds of Greenland,' by our respected Secretary Col. Sabine (Linn. Trans. vol. xii.). These enterprising explorers found the means, during their arduous and protracted expeditions, to add greatly to our knowledge of Arctic zoology, and the results of their labours were brought together and reduced to system in the volumes of the 'Fauna Boreali-Americana,' of which the volume on birds is the production of Dr. Richardson, assisted by Mr. Swainson. The specific descriptions by the former gentleman are a model of accuracy and precision, and the lithographic plates are executed with Mr. Swainson's usual skill.

In his able 'Report on North American Zoology,' read to the British Association in 1836, Dr. Richardson has presented us with a full catalogue of the birds of North America, including Mexico. He enters at some length into the subject of migration, and has incorporated with his own observations those of the Rev. J. Bachman in Silliman's 'American Journal of Science,' 1836.

His Highness the Prince of Canino continues to take a lively interest in the zoology of North America, where so many years of his life were spent. In 1838 he published a very elaborate 'Comparative List of the Birds of Europe and North America,' exhibiting in parallel columns the species which, whether by identity or by close affinity, represent each other in the two countries. This work exhibits some interesting results connected with the geographical distribution of species and of forms. The region between Mexico and the Polar sea approaches in its fauna much more to the European, and less to the tropical American type, than might have been expected. Of 471 North American species of birds, no less than 100 are identical with European kinds. This is due not merely to similarity of climate, but to the comparatively short interval between western Europe and eastern America, which enables nearly all the marine and some of the terrestrial species to pass from the one continent to the other. Another cause is the proximity of northwestern America to Siberia, which has extended the migrations of certain essentially arctic species, and caused them to spread completely round the world to the north of about lat. 50°.

The Prince is at present engaged on an improved edition of the 'List of North American Birds,' in which he now proposes to include the birds of Mexico. This addition will materially modify the numerical results of the former work, as it will introduce a large number of species of a more tropical character than most of those of the United States. It will form a valuable addition to our knowledge, the birds of Mexico being as yet but imperfectly determined and their descriptions scattered through many remote sources. Some of them have been described by Mr. Swainson (Philosophical Magazine, ser. 2, vol. i. and Animals in Menageries), others by Wagler and Kaup, (Oken's 'Isis,' 1832,) and Lesson (Ann. Sc. Nat. ser. 2, vol. ix.). Not a few of the nominal species in Latham's 'Index Ornithologicus' are said to be from Mexico, some of which, taken from the original work of Hernandez, might doubtless be regained to science; others, described from the worthless 'Thesaurus' of Seba, are probably altogether apocryphal.

The voyage of Capt. Cook supplied the earliest materials for the zoology of north-western America. A few Rasorial birds were brought from that country by the botanist Douglas, and others are described by Mr. Vigors in the 'Zoology of Capt. Beechey's Voyage,' 1839. We may regret that no note was taken of the localities of many species brought home by that expedition, and which are described and figured with exactness in the above work. M. Lichtenstein's memoir in the 'Berlin Transactions,' 1838, and the recently published 'Zoology of the Voyage of the Sulphur,' have also furnished some additions to the ornithology of that remote part of the American continent, and twelve species from the Columbia river are described by Mr. Townsend in the 'Journ. Acad. Sc.,' Philadelphia, 1837.

Mr. J. P. Giraud has described several new species of birds from Texas in the 'Annals of the Lyceum of New York,' of which he has given coloured figures in a folio form, under the title of 'Description of Sixteen New Species of North American Birds,' New York, 1841.

Central America.—Of this region of tropical forests (in which Honduras and Yucatan may be geographically included) the zoology is almost unknown. Two or three beautiful birds from that country have found their way into Temminck's 'Planches Coloriées,' a few more are described by M. Lesson in the 'Revue Zoologique,' 1842, and Dr. Cabot, an American naturalist who accompanied Mr. Stephens in his interesting expedition in Yucatan, has enumerated some of the birds which he collected, in the work of the latter gentleman (Incidents of Travel in Yucatan). He considers many of them to be identical with species of the United States, but it is not stated how far this identification rests on a rigorous comparison of specimens from the two countries. Dr. Cabot has given an interesting account of the habits of that beauful bird the *Meleagris ocellata* in the 'Boston Journal of Natural History,' and the habits of *Trogon pavoninus*, another splendid bird of that country, are recorded by M. Delattre in the 'Revue Zoologique,' 1843.

Galapagos Islands.—This small group of islands illustrates that remarkable law which establishes a general coincidence between geographical distribution and zoological affinity. These islands of the Pacific, though several hundred miles distant from the American coast, are yet much nearer to it than to the numerous islands of the Polynesian archipelago, and in conformity with this position we find that the birds of the Galapagos, though belonging to species exclusively confined to these isles, are altogether referable to an American and not to a Polynesian type of organization. This result is derived from the researches of Mr. Darwin, who, in the 'Zoology of the Voyage of the Beagle,' has described several new species from these remote islands.

West Indies.—The ornithology, and I may say the natural history of the West Indies, is far less known than from the long connection of those islands with Europe might have been expected. Of the birds of Cuba a few were described by Mr. Vigors in the 'Zoological Journal,' vol. iii. This island has since been scientifically surveyed by Ramon de la Sagra in his 'Histoire Physique, Politique et Naturelle de l'Isle de Cuba,' in which a considerable number of new species of birds are accurately characterized. Many of the birds of St. Domingo were long since described by Brisson, Buffon and Vieillot, and few if any additions to our knowledge of its productions have been made of late years. The natural history of our own island of Jamaica has experienced a degree of neglect which reflects but little credit upon the energy of individuals or of the government. Almost the whole of our knowledge of its ornithology is derived from the obscure descriptions and wretched figures in Sir Hans Sloane's 'Natural History of Jamaica,' published in the beginning of the last century. A few stray species have since been described by various authors, but nothing like a regular scientific survey of that beautiful and interesting island has yet been, or, judging from appearances, is likely to be, undertaken. The smaller West Indian islands have been equally neglected by naturalists; but few of their natural productions ever reach our museums, and these are too often consigned to the cabinet without being scientifically described or published.

South America.—The birds of Columbia were till a recent period wholly unknown (with the exception of a few brief notices by Humboldt in his 'Recueil d'Observations de Zoologie,' 1811), but a considerable supply of specimens has been lately sent to Europe from the province of Bogota, which have added greatly to our knowledge. Many new species thus obtained have been described by MM. De Lafresnaye, Boissonneau, Bourcier and De Longuemare in the 'Magazin de Zoologie' and 'Revue Zoologique,' and by Mr. Fraser in the 'Proceedings of the Zoological Society.' Many of the birds of that country are beautiful and interesting representatives of the better-known species of Brazil, and the family of Tanagers in particular has lately received large additions from that quarter.

The ornithology of British Guiana is not yet so fully worked out as it deserves to be. Mr. Schomburgk has collected many species during his various journeys in the interior, some of which have been characterized in miscellaneous works; but there is no collective publication of the natural history of that colony.

The ornithology of Brazil, on the other hand, is now very fully known, many species having been described by the older authors, and many more in recent times by Prince Maximilian of Neuwied, Spix, Swainson, and others.

The costly work of Spix, 'Avium species novæ in itinere per Braziliam collectæ,' is valuable rather for the amount of new materials which the travels of that author supplied, than for the skill or diligence with which those materials were digested. A sounder criticism was applied by Prince Maximilian of Wied, who has done much to illustrate the ornithology of Brazil, not only in his travels in that country, and his 'Recueil de Planches Coloriées d'Animaux du Brésil,' but in his 'Beiträge zur Naturgeschichte von Brazilien,' Weimar, 1832. A great number of species are there described in detail, and the work is especially valuable as a supplement and commentary to the writings of Azara and Spix. About 1833 Mr. Swainson commenced an illustrated work on the birds of Brazil, entitled, 'Ornithological Drawings,' but it only attained to about seventy plates. The figures are well drawn and carefully coloured; but they labour under the defect of being unaccompanied by descriptions, without which even the best designs are often insufficient for specific identification. M. Schreiber of Vienna commenced, in 1833, the 'Collectanea ad Faunam Braziliæ,' but only one number of the work was ever published. Several Brazilian birds are also described by Nordmann in the Atlas to Erman's 'Reise um die Erde,' 1835.

Since the publication of the invaluable work of Azara, nothing has been added to the ornithology of Paraguay; but as that country is intermediate to Brazil, Chili and Patagonia, most of Azara's species have been procured by naturalists who have visited the three last-named countries. Many of the birds of Patagonia, Terra del Fuego and the Falkland Isles, are described by Mr. Darwin in the 'Zoology of the Voyage of the Beagle,' and by Capt. King (Zool. Journal, vol. iii. and Zool. Proceedings, 1831).

After the publication of Molina's not very accurate 'Saggio sulla storia naturale del Chili,' fifty years elapsed without any addition being made to the zoology of western South America. About 1831 M. Kittlitz published a short paper on the birds of Chili in the 'Mémoires de l'Académie Impériale de St. Pétersbourg,' in which several new and curious generic forms are for the first time indicated. Descriptions of a few Chilian birds will also be found in the 'Journal de la Navigation de la Frégate Thetis,' 1839, and in papers by M. Meyen in the 'Nova Acta Ac. Leop. Car.,' vol. xvi., and by M. Lesson in the 'Revue Zoologique,' 1842. Subsequently the 'Voyage dans l'Amerique Méridionale,' by M. D'Orbigny, and the 'Zoology of the Beagle,' by Mr. Darwin, have greatly extended our knowledge of this region. Nor ought I to omit the brief but very interesting notes on the birds of Chili by Mr. Bridges, in the 'Proceedings of the Zool. Soc.,' 1843, or the full list of Peruvian birds lately published at Berlin by M. Tschudi, in which many new species are described. Most of the species originally described by Molina are now identified with accuracy, and the long and narrow tract extending the whole length of South America, between the Andes and the Pacific, is shown to possess a peculiar and a highly interesting fauna.

M. A. D'Orbigny, who prosecuted his scientific researches for several years in South America, traversing the interior from Buenos Ayres to Columbia, has reaped a rich harvest of zoology, which is embodied in his 'Voyage dans l'Amerique Méridionale.' Besides discovering many new species of birds, he has identified most of those described by Azara. The plates of his work are however not so perfect as the text, the colouring being too vivid, and the figures unnecessarily reduced in size, when the natural dimensions might have been more frequently retained. He has drawn some interesting conclusions respecting the distribution of species through various zones of southern latitude, and through zones, in some degree corresponding to these, of elevation. Such generalizations, when carefully made, never fail to throw light on philosophical zoology.

3. *Ornithological Monographs.*

No method is so effective in advancing zoological science as that by which an author gives his whole attention to some special group or genus, examines critically all the works of previous writers that relate to it, adds his own original observations, and publishes the result in the shape of a Monograph. I will briefly notice the works of this kind which have appeared of late years.

The different species of *Vultur* known up to 1830 were critically analysed by M. Rüppell in the 'Annales des Sciences Naturelles' for that year, and his remarks must be studied by all who attempt to define the species of that intricate group.

The characters of the family *Strigidæ* and of its subdivisions are treated of by M. I. Geoffroy St. Hilaire in 'Ann. Sc. Nat.,' 1830.

Mr. Swainson published a monograph of the genera *Tachyphonus* and *Tyrannus* in the 'Quarterly Journal of Science,' London, 1826. Although several species have been discovered since, and new genera proposed, yet these papers still possess considerable value. An essay on the *Cuculidæ* by the same author is inserted in the 'Mag. of Zool. and Botany,' vol. i.

M. Ménétries has published in the 'Mém. de l'Acad. Imp. de St. Pétersbourg,' 1835, a monograph of the *Myiotherinæ*, preceded by an historical account of the authors who have treated of this complicated group. This memoir is a valuable contribution to our knowledge, though the series of natural affinities would perhaps have been better exhibited if the *Thamnophili* had been included among the *Myiotherinæ* (passing, as they do, almost imperceptibly into *Formicarius*), and if the so-called *Myiotherinæ* of the East Indies had been formed into a separate section.

We owe to M. L'Herminier some interesting particulars respecting that anomalous and little-known bird, the *Steatornis* of Humboldt (Ann. Sc. Nat., vol. vi. p. 60, and Nouv. Ann. Mus. Hist. Nat., vol. iii.). It appears that this nocturnal bird, which inhabits the caverns of Venezuela and Bogota, can only be classed among the *Caprimulgidæ*, though it differs from all its congeners in its frugivorous habits, while it approaches the *Strigidæ* in many points of structure (as has been well insisted on by M. Des Murs, 'Rev. Zool.,' 1843).

The same indefatigable naturalist has thrown much light on the structure of the genera *Sasa*, *Palamedea*, *Turnix* and *Rupicola*, in the 'Ann. Sc. Nat.,' vol. viii. p. 96, and 'Comptes Rendus,' 1837. The first of these he shows to be a connecting link between the *Insessores* and *Rasores*; the second he places between the *Rallidæ* and *Ardeidæ*; the third he considers to have more affinity to the *Grallatores* than to the *Rasores*; and the last he retains among the *Ampelidæ*.

M. Lesson's monographs of the *Trochilidæ*, entitled 'Histoire Naturelle des Oiseaux Mouches,' and 'Histoire Naturelle des Colibris,' are valuable works for the illustration of species, but the generic subdivisions are not carried into sufficient detail. M. Lesson has elsewhere proposed several generic groups of *Trochilidæ*, and M. Boié has added others; but many of these appear difficult to define satisfactorily. In fact there is no family of birds whose classification is more imperfect and more in want of careful elucidation than the beautiful but bewildering group of Humming Birds. The two volumes of 'Humming Birds' in Sir W. Jardine's 'Naturalist's Library' contain a synopsis of most of the species, but without professing to form a complete monograph.

Other volumes of the 'Naturalist's Library' are devoted to particular groups, but as they only contain selections, and not entire lists of the species, they do not strictly constitute monographs. Such are the useful volumes by Mr. Selby on the 'Pigeons and Gallinaceous Birds,' and by Mr. Swainson on *Muscicapidæ*. A more complete work is the volume by Sir W. Jardine on the *Nectariniidæ*, or rather on the genus *Nectarinia*, containing a very full synopsis of the species of that extensive and beautiful group.

The 'Histoire Naturelle des Oiseaux de Paradis' by M. Lesson, is a useful monograph of an obscure and difficult group of birds, and is worked out with more care and just criticism than is to be found in many others of M. Lesson's publications.

M. Malherbe of Metz is at present engaged on a general history of the *Picidæ*, a work much wanted on account of the many genera and species introduced into this family since Wagler's monograph of *Picus* was published.

Several attempts have been made to compile monographs of the numerous family of *Psittacidæ*, but the subject is yet far from being exhausted. Levaillant in 1801 had figured and described all the species then known, and Kuhl in 1820 published a valuable monograph in the 'Nova Acta Acad. Leop. Car.' Another and a more complete monograph of the *Psittacidæ*, by the industrious Wagler, will be found in the 'Abhandlungen der Baierischen Akademie der Wissenschaften,' 1832. Although some of the author's generic divisions have been criticised as being artificial, yet this paper has a great value for its discrimination of species. Lear's 'Illustrations of the *Psittacidæ*,' 1832, is intended as supplementary to Levaillant's great work 'Les Peroquets.' The lithographic plates are beautifully executed, but as they are unaccompanied by letter-press they hardly belong to the class of monographs.

Another continuation to the work of Levaillant is the 'Histoire Naturelle des Peroquets,' by M. Bourjot St. Hilaire, Paris, 1835–38, folio. Many of the plates are original, others are copied from Spix, Temminck, or Lear; they are executed on stone, and though inferior to the works of Gould and Lear, they are perhaps the best ornithological lithographs which have issued from the French press. The text of this work is prepared with considerable care, but the nomenclature wants precision, the Latin names being often wrong-spelled, and the principle of binomial appellations departed from. Thus the genus *Palæornis* is in one instance designated *Psittacus*, in another *Psittacus sagittifer*, and in a third *Conurus sagittifer*, with the addition in each case of a specific name. What can we say of an author who designates a species as "*Psittacus platycercus viridis unicolor*," but that he is deserting that admirably concise and effective method of nomenclature introduced eighty years ago by the great Linnæus, and is resuming the vague and unscientific generalizations of the ancient naturalists?

I only know by name the 'Monographie der Papageien,' published in Germany by C. L. Brehm.

Some interesting details on the genera *Crotophaga* and *Prionites* were published by Sir W. Jardine in the 'Annals of Natural History,' vols. iv. and vi., and I last year communicated to the same work a paper on the structure and affinities of the genera *Upupa* and *Irrisor* (*Promerops* of some authors), showing that these genera are really allied, though M. Lafresnaye had maintained that they are widely separated (Proc. Zool. Soc., 1840).

Mr. Vigors communicated to the earlier volumes of the 'Zoological Journal' several papers of a monographic character, entitled "Sketches in Ornithology," which are distinguished by close research and careful induction.

Among the ornithological works of this class which have appeared of late years, Mr. Gould's 'Monographs of the *Trogonidæ* and of the *Rhamphastidæ*' occupy a conspicuous place. Of these I need only say that they are executed in the same form and with the same excellence as his other superb publications. Mr. Gould has also published a short monograph of *Dendrocitta* in the 'Zoological Transactions.' He is now collecting materials for monographs of other families, including the *Odontophorinæ*, the *Caprimulgidæ*, and the *Alcedininæ*. Of the *Odontophorinæ*, or American Partridges, the first number has already appeared; and though they are a less gaudy tribe of birds than many others, yet the admirable taste with which Mr. Gould has depicted them renders the work peculiarly attractive. A translation with reduced plates of Gould's 'Monograph of *Rhamphastidæ*' has been published in Germany by Sturm.

Prof. C. J. Sundevall has described some species of *Euphonia* in the 'Kongl. Vetenskaps Academiens Handlingar,' Stockholm, 1834. This paper is supplementary to the monograph 'De genere Euphones,' by Dr. Lund, published at Copenhagen in 1829.

Dr. Rüppell's work, entitled 'Museum Senckenbergianum,' Frankfort, 1836, contains some admirable monographs of the genera *Otis*, *Campephaga*, *Colius*, *Cygnus*, &c. They combine laborious bibliographical research with close observation of structure, and are accompanied by excellent illustrative figures.

Mr. Swainson published in the 'Journal of the Royal Institution,' 1831, an essay on the *Anatidæ*, which though founded on peculiar theoretical views deserves to be consulted even by those who do not agree in the author's conclusions. This memoir prepared the way for Mr. Eyton's 'Monograph of the *Anatidæ*,' 1838, which is in many respects a valuable and accurate work, and is especially useful for its details of anatomical structure. The Latin specific characters might however have been drawn up with more care; and an appendix should have been added, containing the numerous species described by Latham and the old authors, which had not come under Mr. Eyton's observation. No monograph can be considered complete which does not, in addition to the *ascertained* species, enumerate also the *unascertained*, that is to say, those nominal species which for the present exist only in books and not in museums, many of which however will no doubt be again restored to science as real species, while others will be recognised as peculiar conditions of the species we now possess. In this respect, the collection of monographs published by Wagler under the title of 'Systema Avium,' and continued afterwards in Oken's 'Isis,' affords a useful model. It was his custom, after describing those species of a genus with which he was himself acquainted, to append two lists, one of "*species a me non visæ*," and the other of "*species ad genera diversa pertinentes*."

MM. Hombron and Jacquinot have communicated to the *Académie des Sciences* a memoir on the habits and classification of the *Procellariidæ*, of which an abstract is given in the 'Comptes Rendus,' March, 1844, and in which several new subgenera are proposed. Mr. Gould has also extended our knowledge of this obscure group in the 'Annals of Nat. Hist.,' May, 1844.

M. Brandt, of Petersburg, who has made the *Natatores* his peculiar study, has monographed the family *Alcidæ*, and the genera *Phaëton* and *Phalacrocorax*, in memoirs contributed to the Imperial Academy of Sciences at Petersburg.

Professor Sundevall states that there is a monograph of the genus *Dysporus* (*Sula*) in the 'Physiographisk Tidskrift,' Lund., 1837.

Many monographic summaries of different genera will be found in Temminck's 'Planches Coloriées,' Rüppell's works on Abyssinia, and Smith's 'Zoology of South Africa.'

Besides monographs of the larger groups, there are many valuable memoirs on individual species, such as that by M. Botta on *Saurothera californiana* (originally described by Hernandez as a Pheasant, and now properly termed *Geococcyx mexicanus*, Gm. (sp.)) in the 'Nouv. Ann. Mus. Hist. Nat.,' vol. iv.; that by Dubus on *Leptorhynchus pectoralis* and other new generic types, in 'Bullet. Acad. Roy. de Bruxelles;' by De Blainville on *Chionis* (Ann. Sc. Nat., 1836); by Lesson on *Euryceros* (Ann. Sc. Nat., 1831); by Mr. Yarrell on *Apteryx* (Trans. Zool. Soc., vol. i.), &c.

4. *Miscellaneous Descriptions of Species.*

Among recent works of this class, Guerin's 'Magazin de Zoologie,' commenced in 1831, demands notice. This publication, which for the excellence of its scientific matter and its moderate price deserves every encouragement, is rendered the more convenient to the working naturalist by being sold in separate sections. The ornithological portion of this periodical contains valuable papers by Isidore Geoffroy St. Hilaire, Lafresnaye, D'Orbigny, Eydoux, Gervais, L'Herminier, Delessert and others. Many new and important forms are there described and figured with great exactness, and although the authors are not in all cases sufficiently conversant with the writings of British ornithologists, yet they duly estimate the claims of the latter when brought before them.

Upon the whole, the 'Magazin de Zoologie' must be regarded as a work highly creditable to French science, and it is much to be regretted that since the discontinuance of our own 'Zoological Journal' no similar periodical has been set on foot in this country. Such a work might however be easily reproduced if our Zoological Society would attach illustrative plates to their very valuable 'Proceedings,' and give them the form of a Journal, as has lately been done by the Geological Society.

A work closely connected with the 'Magazin de Zoologie' is the 'Revue Zoologique de la Société Cuvierienne,' the object of which is to assert without loss of time the claims of any zoological discovery, by publishing brief but adequate descriptions of new species. The multitude of labourers now at work in the same field, and the importance of adhering to the rule of priority as the basis of systematic zoological nomenclature, render it necessary to publish rapidly and diffuse widely the first announcements of new discoveries. The delays incident to the engraving of plates and the printing of memoirs in scientific Transactions have often robbed original discoverers of their due credit, and introduced confusion and controversy into science: and it is to remedy this evil that the valuable though unpretending 'Revue Zoologique' was established.

Original descriptions of new species are scattered so widely that it is impossible to notice all the recent works in which they occur, and I must therefore confine myself to simply enumerating the more important. Of regular periodical works devoted to natural history in general, and including original contributions to ornithology, I may mention (in addition to those above noticed) the 'Zoological Journal;' Ainsworth's 'Edinburgh Journal of Natural and Geographical Science,' 1829; Loudon's and Charlesworth's 'Magazine of Natural History;' Sir W. Jardine's 'Magazine of Zoology and Botany;' Taylor's 'Annals of Natural History;' and the popular rather than scientific 'Field Naturalist's Magazine' of Prof. Rennie; the 'Naturalist' of Mr. Neville Wood; and the 'Zoologist' of Mr. E. Newman. Among foreign periodicals are Oken's 'Isis;' Wiegmann's 'Archiv;' Kroyer's 'Naturhistorisk Tidskrift;' Van der Hoeven's 'Tijdschrift fur Natuurlijke Geschiedenis;' Wiedemann's 'Zoologisches Magazin;' 'Physiographisk Tidskrift,' Lund; Rohatzsch's 'Munich Journal;' the 'Annales des Sciences Naturelles;' Muller's 'Archiv für Anatomie;' Silliman's 'American Journal of Science,' 'Boston Journal of Natural History,' and the scientific journals of India, Tasmania and South Africa, which I mentioned when speaking of the ornithology of those regions. Among the authorized publications of scientific societies, ornithological details of greater or less amount will be found in the 'Philosophical Transactions;' the 'Proceedings and Transactions of the Zoological Society;' the Transactions of the Linnæan, the Cambridge Philosophical, the Newcastle and the Wernerian Societies; the 'Bulletin de la Société Philomathique des Pyrénées orientales;' 'Actes de la Soc. Linnéenne de Bordeaux;' 'Mémoires de la Soc. Linnéenne de Calvados;' 'Bulletin de l'Académie Royale des Sciences de Bruxelles;' 'Mémoires' and 'Comptes Rendus de l'Académie Royale de France;' 'Annales du Musée d'Histoire Naturelle;' 'Annales de la Soc. Linnéenne de Paris;' 'Mémoires de la Soc. d'Emulation d'Abbeville;' 'Mémoires de la Soc. Académique de Falaise;' 'Mémoires de la Soc. Royale de Lille;' 'Mémoires de l'Académie de Metz;' 'Mémoires de la Soc. des Sciences Naturelles de Neufchatel;' 'Mémoires de la Soc. de Physique de Genève;' 'Jahrbuch der Naturforschenden Gesellschaft zu Halle;' 'Nova Acta Academiæ Cæsareæ Naturæ Curiosorum;' 'Abhandlungen der Baierischen Akademie der Wissenschaften;' 'Abhandlungen der Akademie der Wissenschaften zu Berlin;' 'Kongl. Vetenskaps Akademiens Handlingar,' Stockholm; 'Mémoires' and 'Bulletins de l'Académie Impériale des Sciences de St. Pétersbourg;' 'Annales Universitatis Casanensis;' 'Mémoires' and 'Bulletins de la Soc. des Naturalistes de Moscou;' 'Annale delle Scienze Naturali di Bologna;' 'Nuovo Giornale de'Litterati di Pisa;' 'Memorie della Academia delle Scienze di Torino;' 'Atti dell' Academia Gioenia de Catania;' 'Journal of the Academy of Natural Sciences of Philadelphia;' 'Annals of the Lyceum of Natural History of New York;' 'Transactions of the American Philosophical Society,' and many others.

Of recent works specially devoted to the description and illustration of new objects of zoology in general or of ornithology in particular, the following British ones may be mentioned:—Swainson's 'Zoological Illustrations,' 1st and 2nd series, 1820–33; Donovan's 'Naturalist's Repository;' Jardine and Selby's 'Illustrations of Ornithology,' an excellent work, which I regret to say is now discontinued; Wilson's 'Illustrations of Zoology,' fol. Edinburgh, 1827, an accurate and well-illustrated volume; J. E. Gray's 'Zoological Miscellany,' 1831, containing concise descriptions of new species; Swainson's 'Animals in Menageries,' 1838, (in Lardner's Cyclopædia,) comprising descriptions of 225 species, many of which however had before been published; Bennett's 'Gardens and Menagerie of the Zoological Society,' 1831, valuable for its observations on the habits of living individuals; and Gould's 'Icones Avium,' equal in merit and beauty to his other works.

Among foreign works of the same kind are Temminck's 'Planches Coloriées,' whose merits are too well known to be here dwelt on, and the text of which, if carefully translated and edited, would form an acceptable volume to the British naturalist; Lesson's 'Centurie Zoologique,' containing eighty miscellaneous plates; those relating to ornithology respectably executed, and exhibiting several new forms, especially of Chilian Birds; the 'Illustrations de Zoologie' form a second volume of the same character as the 'Centurie;' Kuester's 'Ornithologische Atlas der auseuropaischen Vögel,' Nuremberg; Dubois' 'Ornithologische Galerie,' Aix-la-Chapelle; (the last two works I know only by name;) Lemaire, 'Hist. Nat. des Oiseaux exotiques,' Paris, 1836, a collection of brief descriptions and very gaudy figures; and Rüppell's 'Museum Senckenbergianum,' a work of first-rate excellence.

5. *Progress of the Pictorial Art as applied to Ornithology.*

The preceding criticisms have chiefly referred to the claims of the descriptive or classificatory portion of the several works noticed, but it may be useful to make a few special observations on the success which has attended the various methods of representing the forms and colours of birds to the eye. In this branch of zoology as in all others the pencil is an indispensable adjunct to the pen. The minute modifications of form which constitute the distinctive characters of genera, and the delicate shades of colour by which alone the specific differences are in many cases indicated, are of such a nature as to be frequently beyond the power of language to define without the aid of art, and it is consequently indispensable that the zoological artist should combine a scientific knowledge of the subject with a perfect command of his pencil. In no branch of zoology are these peculiar talents more requisite than in ornithology, where the varieties of habit and of attitude, the unequalled grace and elegance of form, the remarkable modifications of structure in the plumage, and the endless diversities of colouring demand the highest resources of the painter's skill.

The three principal modes of engraving, namely, wood-engraving, metallic plate-engraving and lithography, have all been applied in turn to the illustration of ornithology.

1. *Wood-engraving.*—For such illustrations of birds as are not intended for colouring, this method is not only the cheapest, but for works of small size it is the best. The works of the immortal Bewick have shown us with what

complete success the structure and arrangement of the feathers, the relative intensities of the colours, and the characteristic expression of the living bird may be transferred to a block of wood by the hand of original genius. Many recent wood-engravers have approached Bewick, but none have yet equalled him. Among the most successful of these the Messrs. Thompson of London must be especially mentioned. Their woodcuts in Yarrell's 'British Birds' are beautiful works of art; in delicacy of execution they often exceed the engravings of Bewick; but the occasional stiffness of attitude in the birds, and a conventional *sketchiness* in the accompaniments, indicate the professional artist and not the self-taught child of Nature.

The beauty of Yarrell's 'British Birds' is much enhanced by improvements in the preparation of paper and ink, and in the mode of taking off the impressions which have been introduced since Bewick's time. It is probable that if the wood-blocks of Bewick, now in the possession of the great engraver's family, were entrusted to one of our first-rate London printers, an edition of Bewick's 'Birds' could be now produced, far superior in execution to any which was issued in the lifetime of the author.

2. *Metallic plate-engraving.*—Line engravings or etchings on copper or steel have been at all times extensively applied to the illustration of ornithological works. Such engravings, if uncoloured, are certainly inferior in effectiveness to good woodcuts, as an example of which I may mention the numerous plates of birds in Shaw's 'Zoology' and Griffith's 'Cuvier,' which though often respectably executed, are almost useless for the purpose of specific diagnosis; and even when carefully coloured, engraved plates rarely approach in excellence, and in my opinion never equal the best examples of lithography. The greater stubbornness of the material involves almost of necessity a certain constraint in the attitudes represented: just as the statues of ancient Egypt which were carved out of hard basalt, never attained the grace and animation which has been conferred upon the tractable marbles of Greece, and the still softer alabaster of Italy. In proof of this I may refer to Temminck's 'Planches Coloriées,' and to the recent works of Lesson, Quoy, D'Orbigny and other French ornithologists. The figures of birds in these plates, though delicately and even beautifully engraved, are often exceedingly stiff and unnatural, a defect owing partly no doubt to too great a familiarity with *stuffed specimens*, but in part also to the unyielding material on which they are engraved. If the Parisian ornithological artists have not the means of studying living nature, they might at least take for their models the designs of Nature's best copyist —Gould.

The defects shown to be incident to *line-engraving* attach indeed in a less degree to *etching*. The resistance to the tool being diminished in the latter process the lines are drawn with greater ease and freedom. Here the main difficulty is to avoid *hardness* and *coarseness* in the delineation of the plumage. Many etchings which are otherwise meritorious, have failed in this point, and the lines which were intended to represent the smooth soft plumage of birds, resemble rather the scales of a fish or the wiry hair of the Sloth or *Platypus*.

The plates of Mr. Selby's 'Illustrations of British Ornithology' are certainly the finest examples extant of ornithological etchings, though they are nearly equalled by some of the plates etched by Sir W. Jardine, Mr. Selby and Captain Mitford in the 'Illustrations of Ornithology.'

In the plates of Audubon's 'Birds of America' line-engraving is combined with aqua-tint, a method which, when well-executed, may be used with advantage to increase the depth and softness of line-engravings or etchings.

3. *Lithography.*—We have next to consider that style of illustration which

is beyond all question the best adapted to ornithology. Lithography possesses all the freedom and facility of *drawing* as contrasted with the laborious mechanical process of *engraving*, and is hence peculiarly fitted to express the graceful and animated actions of birds. Another merit is the expression of *softness* which it communicates to the plumage, and the power of showing the roundness of the forms by a homogeneous shading, instead of the parallel lines and cross hatchings employed in engraving. The lines introduced to represent the individual feathers possess just that amount of indistinctness which we see in the living object, and which adds so much to its beauty.

It is a matter of some pride to us, that while in certain other departments of natural history (especially in fossil conchology) the British lithographers must yield the palm to foreigners, yet in ornithology our own artists have never been equalled. Lithography was, I believe, first applied to the delineation of birds by Mr. Swainson, who soon attained great excellence in the art. His 'Zoological Illustrations,' his plates to the 'Fauna Boreali-Americana,' and his 'Ornithological Drawings of the Birds of Brazil,' possess great merits both of design and execution, as does also Mr. Lear's great work on the *Psittacidæ*. But all these productions are eclipsed by the pencil of Gould, whose magnificent and voluminous works exhibit a gradual progress from excellence to perfection. Temminck, who in 1835 said of Gould's 'Birds of Europe,' "Ils sont d'un fini si parfait, tant pour le dessin, la pose, et l'exacte verité de l'enluminure, qu'on pourrait, avec de si beaux portraits, se passer des originaux montés," would, I am sure, pass even higher encomiums on the 'Birds of Australia,' which Mr. Gould is now publishing. One little fault, and one only can I find in these beautiful drawings, and that is, that the hallux, which in all the *Insessores* is essential to the steady support of the bird, is too often represented as projecting backwards instead of firmly clasping, as it ought, the perch. Mr. Richter and Mr. Waterhouse Hawkins, both of whom have been employed in executing on stone the designs of Mr. Gould, have attained great excellence in the art, as has also Mr. D. W. Mitchell, the able coadjutor of Mr. G. R. Gray in the 'Genera of Birds.' The latter has successfully applied the new art of "lithotinting" to the representation of smooth and hard surfaces, such as those of the beak and legs of birds. He has also in some cases executed the whole plumage in lithotint, producing a beautiful and delicate finish, the effect of which is intermediate between lithography and engraving.

Lithography has never been applied extensively to ornithology upon the continent. The plates in Vieillot's 'Galerie des Oiseaux,' and in the Atlas to Erman's 'Reise um die Erde' are very indifferent, those in Werner's 'Atlas des Oiseaux d'Europe' a shade better, and in the 'Petersburg Transactions' they are tolerably good. The Prince of Canino's 'Fauna Italica,' Nilsson's 'Illuminade Figurer till Skandinaviens Fauna,' and Rüppell's 'Museum Senckenbergianum,' are the only continental works which I have seen, in which the lithographs at all approach to the excellence of the British artists.

The lithographic plates in Spix's 'Avium species novæ in itinere per Braziliam collectæ,' are tolerably executed; but in rather a peculiar style, the legs and beaks of the birds, and in some instances the whole body, being first covered with black, and the lighter parts afterwards scraped off with a sharp point. Examples of this style also occur in some of Mr. Mitchell's plates. In particular cases, especially in representing the scuta of the legs and feet, and the details of black plumage, this method may be adopted with great advantage.

There is a real though somewhat paradoxical cause of the superior excellence of the drawings of Gould and of Swainson, which should not be overlooked. It is, that these artists have in almost every case (when the living bird was not accessible) made their designs from *dried skins*, and not from *mounted specimens*. In the skin of a bird, dried in the usual mode for convenience of carriage, the natural outlines and attitudes are nearly obliterated, and the artist is consequently *compelled* to study living examples, to retain the images thus acquired in his memory, and to transfer them to his design. By the constant habit of thus re-animating as it were these lifeless and shapeless corpses, he acquires a freedom of outline and a variety of attitude unattainable by any other means. But when an artist attempts to draw from a stuffed specimen, he beholds only a fabric of wire and tow, too often a mere caricature of nature, exhibiting only the caprices and mannerisms of an ignorant bird-stuffer. Knowing that the object before him is *intended* to represent nature, he is unconsciously and irresistibly led to copy it with all its deformities. Such is no doubt one cause of the stiff and lifeless designs which we see in the French works, drawn as they mostly are from mounted specimens in the Paris Museums.

6. *Anatomy and Physiology of Birds.*

The most complete general treatise on the anatomy of birds that I am acquainted with is the article *Aves* by Prof. Owen, in Todd's 'Cyclopædia of Anatomy and Physiology.' The author's original investigations on this subject are here combined with those of others, and the whole forms an excellent monograph of the structural peculiarities of the class, as well as of many differential modifications which mark particular groups. Much indeed remains to be added to our knowledge of individual organizations, but those anatomical arrangements which distinguish Birds from the other classes of *Vertebrata* can hardly be described with greater precision or reasoned upon more philosophically than in the work in question. We may indeed regret that this treatise of Prof. Owen is not published in a separate and more accessible form, especially if we consider how essential a knowledge of comparative anatomy is to the scientific zoologist, and what peculiar interest attaches to the anatomy of Birds, as indicating their affinities to Reptiles and to Mammals, and as exhibiting the wonderful arrangements by which their muscular bodies are sustained in a medium at least one thousand times lighter than themselves. We shall however be soon put in possession of Prof. Owen's most recent researches on the anatomy of birds, by the publication of that portion of his 'Hunterian Lectures' which relates to the *Vertebrata*, and which will doubtless be of equal value with the excellent volume already issued on the *Invertebrata*.

Another carefully-prepared summary of ornithic anatomy is that by Prof. M'Gillivray, in the Introduction to his 'History of British Birds.' The author has evidently bestowed much labour, both mental and manual, upon this subject, and has successfully vindicated the claims of comparative anatomy to be considered not an adjunct to, but a part of, scientific zoology. The above work is particularly valuable for its details respecting the organs of digestion, a part of the system to which the author justly attributes great importance, and which he has treated of in a special article in the 'Magazine of Zoology and Botany,' vol. i. *Résumés* of the anatomical peculiarities of birds will also be found in the 'Elémens de Zoologie,' by Milne Edwards, 1837, and in the 'Encyclopædia Britannica' and 'Penny Cyclopædia.' The article *Zoology* in the 'Encyclopædia Metropolitana' also contains a useful treatise on the subject, though it is damaged by the affectation of using new English terms in place of the received Latin terminology of anatomy.

In Dr. Grant's 'Outlines of Comparative Anatomy,' the structure of birds is described with the same accuracy as that of the other classes of animals; but as the work is arranged anatomically and not zoologically, the details of ornithic anatomy are necessarily intermixed with those of the other classes of animals.

Prof. Rymer Jones has given, in his 'General Outline of the Animal Kingdom,' a careful abstract of the anatomy of Birds, including more especially the structure of the eye and the important subject of the development of the ovum. The excellent mode in which the generalities of the subject are treated of, makes us regret that the limits of Prof. Jones's work prevent him from giving a fuller statement of the anatomical characters of the several orders and families.

An excellent synopsis of this subject is contained in Wagner's 'Comparative Anatomy,' of which Mr. Tulk has just published an English translation.

Of special treatises, either on the anatomy of particular organs throughout the whole class, or on the general anatomy of particular groups, many are to be found scattered over the field of scientific literature, and I shall notice some of the more important.

The general subject of the *pneumaticity* or circulation of air through the bodies of birds is ably treated of by M. E. Jacquemin in the 'Nova Acta Acad. Cæs. Leop. Car.' 1842. See also 'L'Institut' and 'Comptes Rendus,' 1836. After minutely describing the modifications of the aërating system in different forms of birds, the author deduces a series of conclusions, and shows that this structure, peculiar to the class of birds, performs the fourfold office of oxidizing the blood,—of enlarging the surface of the body, and consequently the points of muscular attachment,—of diminishing the specific gravity, and of producing a general elasticity which favours the act of flight.

The structure of the ear in birds is treated of in great detail in a memoir by M. Breschet, in the 'Annales des Sciences Naturelles' for 1836, and in a detached treatise on the same subject. After giving an historical sketch of the researches of previous authors, he enters upon an elaborate description of the characters of this organ in various groups of birds. He shows that of the three bones of the tympanum, the *stapes* alone is osseous in birds, while the *malleus* and the *incus*, which in Mammalia are composed of bone, are here represented by cartilaginous processes, and he points out many other minute but important characters which appear to distinguish the ears of birds from those of other *Vertebrata*.

Dr. Krohn has treated on the organization of the iris, and Dr. Bergman on the movements of the *radius* and *ulna* in Muller's 'Archiv für Anatomie,' 1837–9.

The structure of the *os hyoides* in birds, and the affinities of its several parts to the corresponding organs of the other *Vertebrata*, are explained in a memoir by M. Geoffroy St. Hilaire, in the 'Nouvelles Annales du Mus. d'Hist. Nat.' 1832.

M. Müller has described the modifications of the male organs of birds in the 'Abhandlungen der Akad. der Wissenschaften zu Berlin,' 1836.

M. Cornay, in 'Comptes Rendus,' 1844, p. 94, has announced that he finds an important character to exist in the anterior palatine bone, the modifications of which in the various orders he considers to form a more correct basis of classification than any one hitherto employed. Until more attention be paid to this organ than it has yet received, it would be premature to pronounce as to the value of it.

The gradual development of ossification in the sternum of young birds, and the relations of its several parts to the skeletons of other *Vertebrata*, were treated of by M. Cuvier (Ann. Sc. Nat. 1832) and by M. L'Herminier (Ann. Sc. Nat. and Comptes Rendus, 1836–37). These essays involved theoretical views which gave rise to controversies in which MM. Serres and Geoffroy St. Hilaire also took part. The structure of the pelvis and hinder extremities was described by M. Bourjot St. Hilaire in a memoir read to the Académie des Sciences, 1834.

The osteology of the feet of birds is treated of by M. Kessler in the 'Bulletin de la Soc. de Naturalistes de Moscou,' 1841.

The internal temperature of various species and groups of birds is treated of in a general memoir on the subject of Animal Heat, by M. Berger, in the 'Mémoires de la Société de Physique de Genève,' 1836. Dr. Richard King has also published some observations on this subject.

Mr. Eyton has contributed some interesting information on the anatomy of *Menura, Biziura, Merops, Psophodes* and *Cracticus*, which throw much light on the affinities and classification of those genera (Annals of Natural History, vol. vii. *et seq.*).

Amidst the numerous profound researches of Prof. Owen on the comparative anatomy of various portions of the animal kingdom are many original investigations into the structure of such rare birds as have fallen under his scalpel. In the 'Transactions of the Zoological Society' he has described the anatomy of *Buceros cavatus*, showing the points of affinity which the *Bucerotidæ* bear towards the *Rhamphastidæ* on the one hand, and the *Corvidæ* on the other. He has also suggested that the probable design of the gigantic beak in the Hornbills and Toucans is to protect the eyes and head while penetrating dense thickets in quest of the nestling birds on which they feed. Another memoir, of still greater importance, is the elaborate description of the anatomy of the *Apteryx* (Trans. Zool. Soc., vol. ii.), for which our successors even more than ourselves will be grateful to Prof. Owen, seeing that but few years will probably elapse before that rare and extraordinary species will be erased from the list of animated beings. He has also contributed to the 'Proceedings of the Zoological Society' excellent anatomical monographs of the genera *Sula, Phœnicopterus, Corythaix, Pelecanus, Cathartes,* and *Talegalla*. The invaluable descriptive catalogues of the Museum of the Royal College of Surgeons, which are in great measure the work of Prof. Owen, contain a mine of information on the anatomy of every class, and not least on that of birds. The volume which relates to the Fossil Mammalia and Birds is now in the press.

We are indebted to Mr. Yarrell for several accurate notices on the more remarkable structures of certain birds, among which are papers on the anatomy of the *Raptores*, on the xiphoid bone and its muscles in *Phalacrocorax*, and on the muscles of the beak in *Loxia*, published in the 'Zoological Journal;' memoirs on the convolutions and structure of the trachea in *Numida*, the *Gruidæ*, and the *Anatidæ*, which will be found in the 'Linnæan Transactions;' and notices on the anatomy of *Cereopsis, Crax, Ourax, Penelope, Anthropoides* and *Plectropterus*, in the 'Proceedings of the Zoological Society.'

A very elaborate account of the anatomy of *Aptenodytes patachonica*, by Mr. Reid, is published in the 'Proceedings of the Zoological Society,' 1835, and we may regret that this gentleman has not made more such contributions to anatomical science.

There are some very interesting remarks by Mr. Blyth on the osteology of *Alca impennis*, in the 'Proceedings of the Zoological Society,' 1837, showing that in this bird (which is wholly unable to fly) the bones of the extremities are nearly solid and filled with marrow, while in the volatile species of *Alcidæ* the air-cavities of the bones are highly developed, in order to compensate for the shortness of the wings. He adds the important remark, that "when once the object of aërial flight is abandoned, the wings are reduced to exactly that size which is most efficient of all for subaquatic progression; *species of an intermediate character of course never occurring*." This principle of the *necessity of hiatuses* in the natural system (of which numerous other examples might be adduced), is one which I have long regarded as conclusive against that continuity of affinities and symmetry of arrangement which some writers have endeavoured to demonstrate.

Mr. T. Allis of York (whose beautifully prepared ornithic skeletons now in the York Museum are so highly creditable to his skill as an anatomist) has made some observations on the connexion between the furculum and sternum, showing that in certain birds possessing powers of long-continued flight these bones are connected by an intimate symphysis, which in *Pelecanus* and *Grus* amounts to an actual anchylosis. (Zool. Proc., 1835).

The anatomies of *Pelecanus*, *Dicholophus* and *Corythaix*, are described in detail by Mr. W. Martin in the work last quoted.

A paper on the anatomy of *Corvus corone* by M. Jacquemin, will be found in the 'Isis,' 1837, and the osteology of the *Trochilidæ* is described by M. J. Geoffroy St. Hilaire in 'Comptes Rendus,' 1838*.

Several points of ornithic anatomy are treated of by Prof. Wagner in the 'Abhandl. der Baierischen Akad.,' 1837, and the osteology of the genera *Crypturus*, *Dicholophus*, *Psophia* and *Mycteria*, is fully described. The structure of the *Struthionidæ* is beautifully portrayed by D'Alton in his 'Skelete der Straussartigen Vögel,' 1827.

There is a paper by M. Schlegel on the supposed absence of nostrils in the genus *Sula*, in the 'Tijdschrift voor natuurlijke Geschiedenis,' 1839, of which, from being unacquainted with the Dutch language, I regret my inability to give a summary.

The osteology of several groups of *Natatores* is treated of by M. Brandt in an elaborate and highly important paper in the 'Mémoires de l'Acad. Imp. de St. Pétersbourg,' 1839. The researches of this author throw great light upon the classification of many obscure groups, and nothing can be more exact than his figures and descriptions of ornithic osteology.

Mr. Yarrell has paid considerable attention to the subject of *hybridity* (Zool. Proc., 1832, 1836, &c.). The result of his observation seems to be that hybrid birds will occasionally propagate with the pure race on either side, but rarely, if ever, with each other, thus indicating a special provision of nature to preserve the distinctness and permanency of species. Mr. Eyton and Mr. Fuller have also made notes on the same subject (Zool. Proc., 1835). See also a paper by Mr. W. Thompson in the 'Mag. of Zool. and Bot.,' vol. i.

Mr. G. Gulliver, who has made a series of microscopic researches into the blood-corpuscles of the *Vertebrata*, taking exact measurements of these minute bodies in different genera and species, has in the course of this inquiry given a fair share of attention to the corpuscles of birds, and his labours are recorded in the 'Proceedings of the Zool. Soc.,' 1842, &c.

The difficult question of the influence of climate in producing permanent varieties of species is discussed by Dr. C. L. Gloger in a treatise published at Breslau, 1833, and which deserves translation for the use of British naturalists, although the author carries his theory to too great an extent.

The arrangement of the feathers on birds, to which attention was first

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* The 'Disquisitiones Anatomicæ Psittacorum,' by M. Thuet, Turin, 1838, and Kuhlman's dissertation, 'De Absentiâ Furculæ in Psittaco Pullario,' Kiel, 1842, are works which I have not seen.

called by Nitzsch in his 'Pterylologie,' is briefly treated of in a memoir read to the Académie des Sciences by M. Jacquemin (Ann. Sc. Nat., 1836, p. 227), who points out several facts which have not been sufficiently attended to by previous ornithologists.

The various modes by which the changes of plumage in birds at different seasons are effected, whether by actual moulting, by the shedding of a deciduous margin to the feather, or by a change of colour in the feather itself, have been investigated by Cuvier, Temminck, Yarrell (Trans. Zool. Soc., vol. i.), and others. Dr. Bachman of Charleston has made some very interesting observations on this subject in the case of many of the North American birds, which will be found in the 'Transactions of the American Philosophical Society,' 1839.

The subject of moulting, and especially of that remarkable tendency in old female birds to assume the male plumage, is treated of by M. I. Geoffroy St. Hilaire (Ann. Sc. Nat., and Essais de Zoologie Générale, 1841). See also papers by Dr. Butler in the 'Memoirs of the Wernerian Society,' and by Mr. Yarrell in the 'Philosophical Transactions.'

M. de la Fresnaye published in the 'Mémoires de la Soc. Acad. de Falaise,' 1835 (L'Institut, 1837), a paper on *melanism*, or a supposed abnormal tendency in the *Raptores* to acquire a dark plumage, analogous to *albinoism* in other birds. The examples cited are few in number, and not very conclusive, but the subject is deserving of investigation.

Many writers have written descriptive works on the eggs of birds, especially of the European species. Of the older authors on this subject, as Klein, Wirsing, Sepp, Naumann, Schintz, Donovan, Roux, and Thienemann, I need not here speak. In the 'British Oology' of Hewitson the eggs of our native birds are accurately described and figured, and the second edition now publishing attests the popularity of the subject. An 'Atlas of Eggs of the Birds of Europe' is just commenced by A. Lefevre at Paris, the figures of which are well-executed. Of the eggs and nidification of exotic birds our information is very incomplete, and almost the only contributor to this branch of ornithology is M. D'Orbigny, who in his 'Voyage dans l'Amerique Méridionale' gives many figures of eggs and details of nidification, which may aid in clearing up the affinities of certain doubtful forms of the South American continent.

Mr. Gould brought home from Australia a large and interesting collection of eggs and nests, of which we may regret that he has not introduced the figures into the plates of his 'Birds of Australia.' We may hope, however, that when he has completed that great work he will publish an 'Australian Oology,' and perpetuate the knowledge which his unique collection of eggs supplies.

Dr. Carlo Passerini has given an account of the nidification and incubation of *Paroaria cucullata* in a domestic state, in a memoir published at Florence in 1841.

The subject of ornithic oology has been treated of in a philosophical manner by M. Des Murs (Revue Zoologique, and Mag. de Zool., 1842–43). By carefully studying the peculiarities of form, nature of shell and colour in the eggs of various birds, he finds a correspondence between these peculiarities and the structural characters of the several groups, and thus obtains an additional element in the process of classification.

The *number* of eggs laid by birds of different groups and species is the subject of a paper by M. Marcel de Serres (Ann. Sc. Nat., ser. 2. vol. xiii. p. 164), and the author deduces some interesting generalizations upon this subject.

There is a learned treatise on the structure of the egg prior to incubation by Prof. Purkinje, under the title of 'Symbolæ ad Ovi Avium Historiam,' Leipzig, 1830. The structure of the *vitellus* has been investigated by M. Pouché (Comptes Rendus, 1839), and that of the umbilical cord by M. Flourens (Institut, 1835, p. 324), while M. Serres has described the branchial respiration of the embryo of mammifers and birds in the 'Ann. Sc. Nat.,' ser. 2. vol. xiii. p. 141.

Closely connected with oology is the subject of nidification, one of the most interesting branches of ornithological observation, and one which often throws important light on questions of natural affinities. I am not aware of any special work on this subject except the 'Darstellung der Fortpflanzung der Vögel Europa's,' by Thienemann, and the popular 'Architecture of Birds' by the late Prof. Rennie, but the details of the nidification of European birds are contained in most of the works which treat upon them. The nests of the majority of exotic species are still unknown, though Wilson, Audubon, Gould and others have in some measure supplied this deficiency in our knowledge.

The songs and call-notes of birds are very important in their relation to habits and affinities, though from the imperfect mode of indicating these sounds by alphabetical or musical characters, there is much difficulty attending their study. In some cases, such as the relation of *Phyllopneuste rufa* to *P. trochilus*, or of *Corvus corone* to *C. americanus*, the notes of the living birds present clearer specific distinctions than are shown by their physical structure, and the melody of the woods thus becomes no less interesting to the scientific zoologist than it is fascinating to the unlearned lover of nature.

External Terminology.—The series of terms employed by Brisson, Linnæus and Latham, in describing the external parts of birds, were greatly improved in precision and accuracy by the 'Prodromus Systematis Mammalium et Avium' of Illiger. His series of descriptive terms are still generally current, and have undergone comparatively little change. Definitions and figures illustrative of the terms employed in ornithology will be found in most general treatises on the subject, among which Lichtenstein's 'Verzeichniss der Doubletten,' Berlin, 1823, Stephens's 'General Zoology,' Swainson's 'Classification of Birds,' Wilson's article *Ornithology* in 'Encyclopædia Britannica,' the article *Birds* in the 'Penny Cyclopædia,' and M'Gillivray's 'History of British Birds,' may be mentioned as being useful guides to the language of descriptive ornithology.

There is an excellent summary of the different characters used for ornithological classification, and of the due value to be attached to them, by M. I. Geoffroy St. Hilaire, in the 'Nouv. Ann. Mus. Nat. Hist.' 1832, and in the 'Essais de Zoologie Générale' of the same author, 1841. He shows that the value of the emarginated upper mandible, of the feathers and of the caruncles has been much overrated, and points out that the structure of the tongue, the wing and the toes, furnishes characters which have not been duly appreciated. The importance of the feet, as indicating natural affinities by their structural details, is further insisted on by M. de Lafresnaye in the 'Magazin de Zoologie.'

7. *Fossil Ornithology.*

Our knowledge of Birds has received a less amount of extension from the discoveries of Palæontology than perhaps that of any other class of the animal kingdom. Not only are the fossil remains of birds of considerable rarity, and confined principally to the most recent deposits, but when found, they seldom present characters of such a nature as would enable us to predicate generic, much less specific, differences. The generic characters of birds being mostly drawn from the structure of the corneous appendages of the skin, such as the beak, tarsal scuta, claws, remiges and rectrices, are of course effaced in a fossil state, and the study of the bony skeleton has not yet been carried into sufficient detail (except in the case of some very isolated groups) to serve as the basis of generic definitions. The fossil skeletons of birds will nevertheless often guide us to the *family* or even the *subfamily* to which the specimens belong, and as the science progresses a greater amount of precision will no doubt be attained.

Birds, like *Mammalia*, appear not to have generally "multiplied and replenished the earth" until the commencement of the Tertiary epoch. Examples of their existence at an earlier period do indeed occur, but though the evidence of this fact is indisputable, yet the information it conveys is vague and obscure, and we look in vain for such grand palæontological discoveries as those which in the classes *Reptilia*, *Pisces*, *Mollusca* and *Crustacea*, have added whole families and even orders to the zoological system.

Many geologists have supposed that the rarity of fossil Mammals and Birds in the Secondary rocks is owing to the improbability of their becoming imbedded in marine deposits, and not to their non-existence altogether. So far however as it is possible to draw a conclusion from negative evidence, there seem very strong reasons for believing that, in the European hemisphere at least, neither Birds nor Mammals were called into existence prior to the middle of the oolitic period. Let us take the case of the Coal-Measures, a formation of vast extent, and which is proved to have been in some cases a terrestrial deposit, and in others to have been formed in the immediate vicinity of dry land. Yet this vast series of beds, which has been quarried by man to a greater extent than any other, and which contains the remains of Plants and even of Insects in the most perfect state of preservation, has never yet afforded the slightest indication of a Mammal or a Bird. When we contrast this fact with the frequent occurrence of bones of these animals in recent peat-bogs, and in deposits, both marine and lacustrine, of the tertiary epoch, we can hardly attribute the absence of such remains in the Coal-Measures to any other cause than to the non-existence at that period of the two highest classes of *Vertebrata*. The Triassic or New Red Sandstone series leads in the European quarter of the globe to the same conclusion. We there find, in Germany and in Britain, evidences of ancient shores and sandbanks, exposed (probably during the recess of the tide) to the sun and the rain, and presenting the footprints of numerous reptiles which walked upon their surfaces. Now these are the localities to which aquatic birds, as well as certain mammals, love to resort, yet no traces of such animals have yet been met with in any ascertained triassic rock of the eastern hemisphere. The Lias and Lower Oolite again, though strictly marine deposits, contain in many places the remains of plants or of insects which have floated from adjacent shores, but invariably unaccompanied by any fragments of birds or of mammals. In the Stonesfield slate we find the *first* and the *only* indication of Mammalian remains in the whole secondary series; but the bones from that formation, which were once referred to birds, have been proved to belong to Pterodactyles, and no unequivocal examples of birds occur till we reach the horizon of the Wealden beds, where they are exceedingly rare, and apparently unaccompanied by *Mammalia*.

In the American continent however a remarkable case occurs, which seems to prove the existence of birds at a period long anterior to their first appearance in our hemisphere. I allude to the now well-known instance of *Ornithichnites*, or birds' footmarks, in the sandstone of the Connecticut valley, first discovered by Dr. J. Deane, and described by Prof. Hitchcock in the 'American Journal of Science,' 1836–37. (See also Buckland's 'Bridgewater

Treatise,' pl. 26 *a* and *b*, and 'Ann. Sc. Nat.' ser. 2. vol. v. p. 154.) Two questions arise in connexion with these impressions; first, whether they are really produced by birds; and secondly, what is the age of the rock in which they are found. The first question seems to be now finally settled in the affirmative, some of the impressions being so nearly identical with those of certain existing *Grallatores* and *Rasores* as to convince the most incredulous. The footmarks are evidently due to Birds of several distinct genera, some of which present structures as anomalous as those found in the Reptiles and Fish of the same remote epoch. The greater part, however, appear clearly referable to Wading Birds allied in structure to the *Charadriidæ* or *Scolopacidæ*. Some are of such a gigantic size that we can only seek their affinities among the *Struthionidæ*, and others appear to have had the tarsi clothed with feathers or bristles, a character which would exclude them from the *Grallatores* as at present defined, though, judging from the impressions made by living birds in snow, I think this appearance may possibly be due to the *trailing* action of the foot before it takes its hold of the ground. One very remarkable form (if really belonging to a bird) has the outer and middle toe united as in the so-called Syndactyles of Cuvier, and is further distinguished by all the four toes pointing forwards (neither of which characters are in the existing fauna ever found in ambulatory birds). Such anomalous structures however (reasoning from the analogy of the fish and reptiles of the older rocks) appear rather to confirm than to disprove the genuineness and antiquity of these Ornithichnites; and as there is no other known class of animals to which they can by possibility be referred, it would be very unphilosophical to deny them to be the footmarks of birds, to which they bear so strong a resemblance.

In his 'Report on the Geology of Massachusets,' Dr. Hitchcock has described no less than twenty-seven species of these footmarks, and in the 'Reports of the American Association of Geologists and Naturalists, 1843,' he has added five more. (See also Silliman's Journal of Science, Jan. 1844.) One of these much resembles the footprint of a *Fringilla*, others are similar to those of *Fulica*. In all these impressions, the phalanges of the toes obey the same numerical law which prevails, with hardly an exception, in the feet of existing birds*. They are accompanied in some cases by reptilian footmarks resembling those of *Chirotherium*, which are at once distinguished from the ornithic impressions by being *quadruped*, and by the forward position of the thumb.

Granting then that we have here the genuine indications of an ancient ornithological fauna, of which no other traces than these footmarks have been found, we have next to consider the geological age at which they were formed. Now it appears that the phænomena of superposition merely show that this deposit is intermediate between the Carboniferous and Cretaceous series. Could we have availed ourselves of such a latitude for speculation, the analogy of the oldest fossil birds found in the eastern hemisphere, would lead us to adopt the *latest* period within the above limits for fixing the age of these impressions. It has been announced however, both by Dr. Hitchcock and by Mr. Lyell (Proc. Geol. Soc. vol. iii. p. 796), that the only recognizable organic remains discovered in this deposit are Fish belonging to the genera *Palæoniscus* and *Catopterus*, and as these genera have never been found above the Triassic series, we are compelled to follow Dr. Hitchcock in refer-

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* The remarkably simple law referred to is this: that if we consider the metatarsal spine of certain *Rasores* (and which is wanting in all other birds) as the first toe, the hind toe as the second, and the inner, middle, and outer toes as the third, fourth, and fifth, the number of phalanges is found to progress regularly from one to five. The only exceptions are in the *Caprimulgidæ*, *Cypselus*, and one or two others.

ring the sandstone of Connecticut to the New Red system. These Ornithichnites therefore, abounding in this ancient formation, and separated by so vast an interval of time from the oldest traces of fossil birds in our own hemisphere, remain as one of those anomalies which serve to curb the eager spirit of generalization, and to teach us that Nature fulfils her own designs without regard to human theories. Let us hope that the American geologists will never rest till they have discovered some osseous remains of the *raræ aves* whose foot-prints have given rise to such perplexing questions.

The rest of the subject of Fossil Birds may be briefly noticed. The oldest example which I can meet with of their actual occurrence is mentioned in Thurmann's 'Soulèvemens Jurassiques,' (as quoted by Von Meyer, 'Palæologica,') who remarks however that the statement seems to require confirmation. It is there stated that the fossil remains of Birds occur, in company with those of Saurians and Tortoises, in the limestone of Soleure, which is considered equivalent to the Portland beds.

A better authenticated instance is recorded by Dr. Mantell (Fossils of Tilgate Forest, p. 81; Geol. Trans., vol. v.; Proc. Geol. Soc., vol. ii. p. 203), who describes certain bones from the Wealden beds of Sussex, which he shows (and his opinion is backed by that of Cuvier and of Owen) to belong to Waders and probably to *Ardeidæ*. Other bones from the same locality apparently belong to birds, yet present a nearer approach to the reptilian type than any known existing genus.

Another example of a fossil bird from the secondary series is mentioned by Dr. Morton (Synopsis of Cretaceous Rocks of United States), who procured a specimen which he refers to the genus *Scolopax*, in the ferruginous sand of New Jersey. This formation he considers to represent the Greensand of Europe, and though its precise equivalent may be somewhat doubtful, there is no doubt of its belonging to the Cretaceous series.

In the "Glaris slate" of Switzerland, a member of the lower portion of the Cretaceous system, a nearly entire skeleton of a bird resembling a Swallow, has been found by Professor Agassiz.

The Chalk of Maidstone has supplied Lord Enniskillen with some fragments of the skeleton of a large natatorial bird, considered by Professor Owen to be most nearly allied to the Albatros (Proc. Geol. Soc., vol. iii. p. 298; Geol. Trans., vol. vi.).

Proceeding to the Tertiary series, we find that ornitholites begin to appear in greater abundance. Here, as in every other department of the animal kingdom, we perceive a rapid approximation to the fauna which is characteristic of the period in which we now live.

The Eocene clays of the Isle of Sheppey have produced the bones of a bird affording almost the only example of a decidedly new ornithological form which has been rescued from the ruins of past geological ages. The sternum of this bird is fortunately preserved, and Professor Owen having worked out its affinities to all known genera with his usual sagacity and success, has arrived at the conclusion that it forms a new genus among the *Vulturidæ*, which he has denominated *Lithornis* (Proc. Geol. Soc., vol. iii. p. 163). This interesting specimen will soon be described in Prof. Owen's work on 'British Fossil Mammalia and Birds,' now in course of publication.

In Kœnig's 'Icones fossilium sectiles,' fig. 91, some fragments of bones from the Isle of Sheppey are delineated, which the author considers to belong to a natatorial bird, and which he designates *Bucklandium diluvii*. If the original specimens are in existence they would well deserve further examination.

The remaining instances of fossil birds from the Tertiary formations call for but little remark. The fragments which have been found are either undistinguishable, or at any rate have not yet been distinguished, from the genera and species of the existing creation, though it is highly probable that new forms might in some cases be detected if they were subjected to rigid examination. In the Tertiary and for the most part Eocene strata of the continent, birds' bones have been found in Auvergne, at Pont du Chateau and Gergovia, overlaid by beds of basalt, and in one instance accompanied by fossil eggs; in the Cantal, at Perpignan, Montpellier, Wiluwe, St. Gilles, Sansan (where eggs have also been found), Montmartre, Monte Bolca, Œningen, Kaltennordheim, Ottmuth in Upper Silesia, Westeregeln near Magdeburg, and Neustadt in the Hardt, and are recorded in the writings of Dufrénoy, Bravard, Croizet, Jobert, Marcel de Serres, Karg, Cuvier, Mösler, Germar, Von Meyer, &c. Birds' feathers have been found fossil at Monte Bolca, Aix and Kanstatt.

Proceeding to the newer Tertiary beds, we meet with remains of birds in the Crag of Suffolk and in the Plistocene fluvio-lacustrine beds at Lawford (Buckland). M. Lund, whose researches into the bone-caverns of Brazil have already very greatly extended our knowledge of fossil Mammalia, has announced that he has also obtained a considerable variety of fossil birds, including a Struthious species larger than the existing *Rhea* of America; but these remains have not as yet I believe been fully investigated. The same remark also applies to the ornithic remains found by Dr. Falconer in that mine of palæontology the Siwalik Hills of India. Amidst the extraordinary remains of Mammals and of Reptiles obtained by that gentleman, the bones of several species of Birds were found mostly referable to the Grallatorial order, and exhibiting in some cases very gigantic proportions. As Dr. Falconer's collections are now in course of arrangement at the British Museum, we may hope soon to learn more particulars of these interesting ornithic fossils.

The *Gryphus antiquitatis* of Schubert, a supposed colossal ornitholite from Siberia, appears to be either altogether apocryphal, or to be founded on the cranium of a Rhinoceros, mistaken for that of a bird.

In bone-caverns fossil birds have been found in company with extinct Mammalia at Kirkdale (Buckland), Bize in the south of France (Marcel de Serres), Avison, Sallèles, Poudres near Sommières, and Chokier near Liège (Von Meyer).

The bones of birds are of frequent occurrence in the osseous brecciæ which fill the fissures of limestone on the coasts of the Mediterranean, but these are probably referable in many cases to the recent epoch. They are recorded as occurring at Gibraltar (Buckland), Cette, St. Antoin and Perpignan (Cuvier), Nice (Risso), and Sardinia (Wagner, Nitzsch and Marmora).

I may here mention the remarkable instances of birds which belong to the existing epoch of the world, but have become extinct in recent times. The first is the well-known case of the Dodo, a bird insulated alike in structure and in locality, and which being unable to fly, and confined to one or two small islands, was speedily exterminated by the thoughtless pioneers of civilization. Most fortunately a head and foot of this bird still exist in the Ashmolean, and another foot in the British Museum; and with these data, aided by the descriptions of the old navigators, we are in some degree informed as to the structure and natural history of this anomalous creature. The memoirs on the Dodo by Mr. Duncan in the 'Zoological Journal,' vol. iii., and by M. De Blainville in the 'Nouvelles Annales du Muséum d'Hist. Nat.,' vol. iv., are highly interesting, and there is an admirable synopsis of the whole subject from the pen of Mr. Broderip in the 'Penny Cyclopædia,' article *Dodo*.

The bird described by Leguat (Voyage to the East Indies, 1708,) as inhabiting the island of Rodriguez so recently as 1691, and termed by him *Le*

Solitaire, appears evidently to have been another lost species of terrestrial bird distinct from the Dodo, and more allied in its characters to existing species of *Struthionidæ.* It is therefore probable that the supposed bones of the Dodo, described by Cuvier as found beneath a bed of lava in the Mauritius, but which M. Quoy states to have been in fact brought from Rodriguez, as well as the bones from the latter island presented by Mr. Telfair to the Zoological Society (Proc. Zool. Soc., part i. p. 31), but which have been unfortunately mislaid, belonged, not to the Dodo, as Cuvier supposed, but to the *Solitaire.* On this supposition we can the better account for a fact which threw doubt at the time upon Cuvier's identification of the bones at Paris, namely, that the sternum in this collection presented a mesial ridge, indicating strong pectoral muscles. Now Leguat tells us that the *Solitaire,* though unable to fly, had its wings enlarged at the end into a knob, with which it attacked its enemies, a structure which would require large pectoral muscles and a sternal crest. These bones and others, said to be from the Mauritius, in the Andersonian Museum at Glasgow and at Copenhagen, require further investigation, and every additional fragment that can be recovered from the caverns or alluvial beds of Mauritius, Rodriguez, or Bourbon, ought to be most carefully preserved.

The island of Bourbon appears to have been inhabited at a recent date by two species of birds allied to, but distinct from, the Dodo of Mauritius and the *Solitaire* of Rodriguez. I lately found in a MS. journal given by the late Mr. Telfair to the Zoological Society, an exact and circumstantial account of two species of Struthious birds which inhabited Bourbon in 1670 (Zool. Proceedings, April 23, 1844, Ann. Nat. Hist., and Phil. Mag., Nov. 1844). It appears then that this small oceanic group of islands possessed several distinct species of this anomalous family, the whole of which were exterminated soon after the islands became tenanted by man.

Evidence of the recent existence and probable extinction of another Struthious bird has very lately come to light in New Zealand, where its bones are occasionally met with in the alluvium of rivers. The first portion that was brought to this country was a very imperfect fragment of a femur, which Professor Owen did not hesitate to assign to an extinct gigantic bird allied to the Emeu (Trans. of Zool. Soc., vol. iii. p. 29). This bold conclusion, which from the imperfection of the data seemed prophetic rather than inductive, was speedily confirmed by the arrival of fresh consignments of bones, and we are now in possession of a considerable portion of the skeleton of this ornithic monster, which has been appropriately named by Professor Owen *Dinornis.* That skilful anatomist has even been enabled, from the materials already received, to point out no less than *five* species of this genus, differing in stature and the proportions of their parts (Proc. Zool. Soc., Oct. 1843). These birds, *if extinct,* must have become so in very recent times, and probably through human agency; but it is as yet by no means certain that they do not still inhabit the unexplored interior of the middle island of the New Zealand group. See notices by Rev. W. Cotton in 'Zool. Proc.,' 1843, and by the Rev. W. Colenso in the 'Tasmanian Journal,' reprinted in the 'Annals of Nat. Hist.,' vol. xiv.

Another very interesting bird of the same region, the *Apteryx,* is now threatened with the fate which has befallen the Dodo and (as presumed) the *Dinornis.* Civilized man has already upset the balance of animal life in New Zealand. It is stated by Dieffenbach that *Cats,* originally introduced by the colonists, have multiplied greatly in the woods and are rapidly reducing the numbers of the *Apteryx,* as well as of other birds, so that unless some Antipodean Waterton will disinterestedly enclose a park for their preservation, these extraordinary productions of the Creator's hand will soon perish from the face of the earth.

8. *Ornithological Museums.*

The conservation of specimens for the purpose of reference is no less essential to the progress of zoology than the description of species in books, and in the case of ornithology there certainly is no scarcity of collections, both public and private, of illustrative specimens. Unfortunately, indeed, *classification*, which is no less important, though far less easy, than *accumulation*, is too often wanting or imperfect in such repositories, and their scientific utility is thus very greatly diminished. I may congratulate the zoological world, however, that this is no longer the condition of our great national collection, the British Museum. Without adverting to the immense improvements introduced in the last few years into all its other departments, I need only remark that the ornithological gallery, from the beauty of its arrangements and the extent of its collections, rivals, if not exceeds, the first museums of the continent. The scientific classification of the specimens is making great progress, under the able superintendence of the two Messrs. Gray, and ornithologists will soon possess in this collection a standard model which may be applied with advantage to other museums. This latter object will be greatly aided by the recent publication of catalogues, scientifically arranged by Mr. Gray, of all the species contained in the museum.

These catalogues, which are brought out in an accessible form, are calculated to be of great service to science. The classification and the scientific nomenclature are based on sound principles, and are corrected by the latest observations of zoologists, and every specimen is separately enumerated, with its locality and the name of its donor, which is especially important in a collection containing the *type-specimens*, from which original descriptions have been made. The zoological catalogues of the British Museum will now become standard works of reference, exhibiting both the riches and the desiderata of our national collection, and setting an example which we may hope to see followed by the great public museums abroad. The catalogue of the Mammalia was published last year; of the Birds, the *Accipitres*, *Gallinæ*, *Grallæ* and *Anseres* are already issued, and the other portions will speedily follow. Dr. Hartlaub has been the first to profit by this spirited example, and has published an excellent catalogue of birds in the Bremen Museum.

Another collection, of almost equal value, is that of the Zoological Society, now in progress of arrangement in a new building at the Society's Gardens. Among private cabinets I may mention Mr. Gould's Australian collection as one which possesses a peculiar scientific value. It consists of selected specimens of the entire ornithology of Australia, the sexes, dates and localities of each being indicated, and as these specimens form the standard authorities for the accuracy of Mr. Gould's figures and descriptions, we may hope that this unique collection may be preserved for reference in some permanent repository. But I must abstain from further details, as it would be impossible to give anything like a fair report on the individual merits of the numerous ornithological museums now extant without a far more extended personal inspection of them than I have had opportunity to make. It may however assist the student to be furnished with a list of all the more important collections of birds which have come to my knowledge (though many others doubtless exist); and I shall venture on no other criticism of them than merely to distinguish those general collections which are of first-rate importance by CAPITALS, and those which are confined to British ornithology by *Italics*.

ENGLAND:—Public Museums.—London (1. BRITISH MUSEUM; 2. ZOOLOGICAL SOCIETY; 3. EAST INDIA COMPANY; 4. Linnæan Society; 5. United Service Institution; 6. College of Surgeons; 7. London Missionary Society); Newcastle-on-Tyne; Carlisle; Kendal; Durham; Scarborough; Leeds; York; Lancaster; Manchester; Liverpool (Royal Institution); Nottingham; Derby; Chester; Shrewsbury; Ludlow; Hereford; Burton-on-Trent; Birmingham (School of Medicine); Warwick; Cambridge; Norwich; Bury St. Edmunds; Saffron Walden; Oxford; Worcester; Cheltenham; Bristol; Plymouth; Bridport; Gosport (Haslar Hospital); Chichester; Rochester; Chatham (Fort Pitt); Canterbury; Margate.

Private Museums.—EARL OF DERBY, Knowsley; Lord Say and Sele, Erith; Earl of Malmesbury, Christchurch, Hants; Messrs. Hancock and Dr. Charlton, Newcastle; P. J. Selby, Twizell; *Dr. Heysham*, Carlisle; — Crossthwaite, Keswick; J. R. Wallace, Distington, Cumberland; — Newell, Littleborough, Lancashire; A. Strickland, Bridlington Quay; *J. Hall*, Scarborough; C. Waterton, Walton Hall; *W. H. R. Read*, York; *G. S. Foljambe*, Osberton; *Rev. A. Padley*, Nottingham; H. Sandbach, Liverpool; *Rev. T. Gisborne*, Yoxall, Staffordshire; T. C. Eyton, Donnerville, Shropshire; *J. Walcot*, Worcester; H. E. Strickland, Oxford; *Rev. Dr. Thackeray*, Cambridge; J. H. Gurney, Earlham Hill, Norfolk; R. Hammond, Swaffham; Rev. G. Steward, Caistor; *E. Lombe*, Melton Hall, Norfolk; Rev. C. Penrice, Plumstead; *J. R. Wheeler*, Wokingham; — Dunning, Maidstone; *C. Tomkins*, M.D., Abingdon; W. V. Guise, Rendcomb; T. B. L. Baker, Hardwicke, Gloucester; *Rev. A. Mathew*, Kilve, Somerset; Dr. Roberts, Bridport; Dr. E. Moore, Plymouth; J. H. Rodd, Trebartha, Cornwall; H. Doubleday, Epping; *W. Yarrell*, J. Gould, J. Leadbeater, and G. Loddiges, London.

WALES:—Private.—L. L. Dillwyn, Swansea.

SCOTLAND:—Public.—Edinburgh; Glasgow (1. Hunterian Museum; 2. Andersonian Museum; 3. King's College); Aberdeen; St. Andrew's; Kelso; Dumfries.

Private.—Sir W. Jardine, Jardine Hall; Capt. H. M. Drummond, Meggineh Castle, Errol; *E. Sinclair*, Wick; Duke of Roxburgh, Fleurs; Dr. Parnell, Edinburgh.

IRELAND:—Public.—Dublin (1. Royal Dublin Society; 2. Natural History Society; 3. *Ordnance Collection*; 4. Trinity College); Belfast Museum.

Private.—*Dr. Farran* and *T. W. Warren*, Dublin; *Dr. Burkitt*, Waterford; *Dr. Harvey*, Cork; *J. V. Stewart*, Rockhill, Donegal; *R. Davis*, Clonmel; *Rev. T. Knox*, Toomavara; *W. Thompson*, Belfast.

FRANCE:—Public.—PARIS; STRASBURG; Bordeaux; Clermont; Lyons; Boulogne; Caen; Rouen; Metz; Epinal; Marseilles; Avignon; Arles; Nismes; Montpellier.

Private.—Prince Massena, Paris; MM. Baillon and De Lamotte, Abbeville; Lesson, Rochefort; Allard, Montbrisson; Baron de Lafresnaye, Falaise; Fleuret, Bifferi, Boursier, and Jourdan, Lyons; Crespon, Nismes; Degland, Lille; Bequillet, Toulouse.

BELGIUM:—Public.—BRUSSELS; Ghent; Louvain; Liège; Cologne (Jesuits' College); Tournay.

Private.—M. Kets, Antwerp; L. F. Paret, Ostend; M. Dubus, Brussels.

HOLLAND:—Public.—LEYDEN; Haarlem.

DENMARK:—Public.—Copenhagen.

NORWAY:—Public.—Christiania; Bergen; Drontheim.

Private.—Prof. Esmark, Christiania.

SWEDEN:—Public.—Stockholm; Lund; Upsal; Gottenburg.

Private.—Mr. R. Dann, Sioloholm, Gottenburg.

RUSSIA:—Public.—ST. PETERSBURG; Moscow; Casan; Odessa.

PRUSSIA:—Public.—BERLIN.

AUSTRIA:—Public.—VIENNA; Trieste; Laibach.

WESTERN GERMANY:—Public.—Bonn; Mannheim; Mayence; FRANKFORT-ON-MAIN; Darmstadt; Heidelberg; Karlsruhe; Freiburg; MUNICH; Stutgart; Dresden; Göttingen; Greifswald; Bremen.

Private.—Prince Maximilian, Neuwied; C. L. Brehm; J. A. Naumann, Dessau; Dr. Hartlaub, Bremen.

SWITZERLAND:—Public.—Basle; Neufchatel; Berne; Soleure; Geneva; Fribourg (Jesuits' College); Sion (Jesuits' College).

ITALY:—Public.—TURIN; Pavia; Parma; Bologna; FLORENCE; Rome (Academia della Sapienza); Genoa; Nice; Pisa; Naples.

Private.—Prince of Canino, Rome; Prince Aldobrandini, Frascati; Marchese Costa, Chambery; Marchese Breme, Turin; Signor Passerini, Florence; C. Durazzo, Genoa; Count Contarini, Venice; Contessa Borgia, Velletri; Signor Antenori, Perugia; Signor Costa, Naples.

SPAIN:—Public.—Madrid; Gibraltar.

IONIAN ISLANDS:—Public.—Corfu.

GREECE:—Public.—Athens.

MALTA:—Private.—Signor Schembri.

NORTH AMERICA:—Public.—Montreal; Cambridge; Salem; Philadelphia (1. Academy of Sciences; 2. Peale's Museum); Charleston; New York; Mexico.

Private.—Signor Constancia, Guatemala.

AFRICA:—Public.—Cape Town.

INDIA:—Public.—Calcutta.

Private.—T. C. Jerdon, Nellore.

AUSTRALIA:—Public.—Sydney; Hobart Town.

In connexion with Museums, the subject of Taxidermy may be briefly noticed. Although in acquiring the somewhat difficult art of preparing the skins of birds for collections, practice is far more important than precept, yet useful hints may often be obtained from the treatises which have been published on the subject. Among the best of these may be mentioned Mrs. Lee's 'Taxidermy,' Swainson's 'Taxidermy' in 'Lardner's Cyclopædia,' Waterton's 'Wanderings,' and his 'Essays in Natural History,' Boitard's 'Manuel du Naturaliste Préparateur,' Brehm's 'Kunst Vögel als Balge zubereiten,' &c., Weimar, and Kaup's 'Classification der Säugthiere und Vögel,' Darmstadt, 1844.

Ornithological Libraries.—It is needless to enumerate all the scientific libraries in which the subject of ornithology is adequately represented, especially as the museums above-mentioned are in most cases accompanied with appropriate collections of books. Of libraries unconnected with museums I may notice, as especially useful to the ornithological student, the Radcliffe at Oxford, the Royal Societies of London and of Edinburgh, and the fine collection of zoological works formed by Mr. Grut of Edinburgh, to whom I am indebted for access to several rare works.

9. *Desiderata of Ornithology.*

Having now given an account of the recent progress and present state of Ornithology, I will conclude with pointing out the *desiderata* of the science, showing the deficiencies which require to be supplied in order to refine the crude mass of knowledge already extracted from the mine, and to make further researches into the storehouses of Nature.

1. There is a great want of increased precision and uniformity in the value of the genera, and of the superior groups which various authors have introduced into ornithology. All groups of the same rank are supposed in theory to possess characters of the same value or amount of importance, and the object of the naturalist should be to bring them as nearly as possible to this state of equality. It must indeed be admitted, that no certain test seems to have been yet discovered for weighing the value of zoological characters. The importance of the same character manifestly varies in different departments of nature, and must therefore be estimated by moral rather than by demonstrative evidence. The real test of the value of a structural character ought to be its influence on the economy of the living animal, but here we too often have to lament our ignorance or our false inductions, and in many cases we are wholly unable to detect the relations between structure and

function. More definite principles of classification may hereafter be discovered, and meantime all that we can do is to arrange our systems according to sound reason and without theoretical prepossession. By care and judgement much may be done to give greater regularity and exactness to our methods of classification, either by introducing new groups where the importance of certain characters requires it, or by rejecting such as have been proposed by others on insufficient grounds. At the present day many authors are in the habit of founding what they term "*new genera*" upon the most trifling characters, and thus drowning knowledge beneath a deluge of names. As this is a point of great importance to the welfare of zoology in general, I may be excused for dwelling on it for a few moments.

In the subdividing of larger groups into genera, even in the strictest conformity with the natural method, there is evidently no other rule but *convenience* to determine how far this process shall be carried. However closely the species of a group may be allied, yet as long as any one or more of them possess a character which is wanting to the remainder, it will always be in the power of any person to partition off such species and to give them a generic name. Take the very natural group *Parus* for instance, as restricted by most modern authors (i. e. *Parus* of Linnæus, deducting *Ægithalus* and *Panurus*). First we may separate the *long-tailed* species, and follow Leach in calling it generically *Mecistura*. Of the remaining *Pari*, we may make a genus of the *crested* species (*P. cristatus*), then another of the *blue* species with short beaks (*P. cæruleus*, &c.), a third of *the black and yellow* group (*P. major*, &c.), and a fourth of the *gray* species (*P. palustris*, &c.). [N.B. Generic names have actually been given to these groups by Kaup in his 'Skizzirte Entwickelungsgeschichte der Europaïschen Thierwelt.'] But another author may go still further, and may again subdivide the groups above enumerated, a process which would lead to the absurd result of making as many genera as there are species, or in other words, of giving to each species *two specific* names and *no generic* one. Therefore genera should not be subdivided further than is *practically convenient* for the purpose of fixing really important characters in the memory; and seeing that there are already more than 1000 genera provided for the 5000 species of birds (which are probably all that can be said to be *accurately* known) it seems evidently inexpedient to increase the number of genera, except in the comparatively rare cases where new forms are discovered, or really important and peculiar structures have been overlooked.

The precise rank in the scale of successive generalizations which shall be occupied by those groups which we term *genera* is then a matter of *convenience*, and consequently of *opinion*. Nature affords us no other test of the just limits of a genus (or indeed of any other group), than the estimate of its value which a competent and judicious naturalist may form. The boundaries of genera will therefore always be liable in some degree to fluctuate, but this is unavoidable, and it is a less evil than to give an unlimited license to the subdivision of groups and the manufacture of names. The only remedy for this excessive multiplication of genera, is for subsequent authors who think such genera too trivial, not to adopt them, but to retain the old genus in which they were formerly included*.

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* It is usual where this is done to retain the groups, which are thus deprived of a *generic* rank, under the title of *subgenera*. There appear to me however to be great objections to the adoption of *subgeneric names* in zoology. First, it would introduce into a science already overloaded by the weight of its terminology, an additional set of names whose rank is not (like that of families, subfamilies and genera) indicated by the *form* of the word, but which are undistinguishable to the eye from real generic names, and would therefore be perpetually confounded with them. Secondly, subgenera would greatly interfere with the harmonious working

We may obtain a great amount of fixity, in the position at least, if not in the extent of our groups, by invariably selecting a *type*, to be permanently referred to as a standard of comparison. Every family, for instance, should have its *type-subfamily*, every subfamily its *type-genus*, and every genus its *type-species*. But it must not be supposed, with some theorists, that these types really exist as such in nature; they are merely examples or illustrations selected for convenience to serve as permanent fixed points in our groups, whatever be the extent which we may give to their boundaries. By adhering to this notion of types we may often indicate these groups with greater precision than it is possible to do by means of definition alone.

2. Another desideratum in ornithology is to discover some sure mode of distinguishing *real species* from *local varieties*. The naturalists of one school are disposed to attribute nearly all specific distinction to the accidental influence of external agents, while others regard the most trivial characters which the eye can detect as indicating real and permanent species. Between these two extremes, the judicious and practised naturalist has seldom much difficulty in keeping a middle course, and perhaps in ornithology the cases of ambiguity are less frequent than in many other departments of nature; still the student will be sometimes at a loss to distinguish between those characters which were impressed on a species at its creation, and those which may be reasonably attributed to external agents, and we must look for further research to solve these difficulties.

3. We are greatly in want of more information as to the habits, anatomy, oology, and geographical distribution of the majority of exotic species. With no other data than are furnished by dried skins, we are too often compelled to guess at, rather than to demonstrate, the true affinities of species. However essential may be the arrangement of specimens in museums, they supply only a portion of the requisite evidence, and a vast and fascinating field of research awaits the naturalist who shall devote himself to *observing*, as well as *collecting*, the ornithology of foreign regions*. The anatomy of many genera and even families of birds is wholly unknown, and it would be well if some student would devote himself especially to this department, and endeavour to make a *classification of birds by their anatomical characters alone*. If such a system were found to coincide with the arrangements which have been based on external characters, the strongest proof would be furnished of its reality and truth.

4. There yet remain many extensive regions of the world, of whose ornithology we know little or nothing. Great as have been the zoological collections made of late years by individuals and governments, there is still much virgin soil for the naturalist to cultivate. The birds of the vast Chinese empire are only known by the rude paintings of the natives, though

of the "binomial method," that mainspring of modern systematic nomenclature; for one author would habitually indicate species by their *generic* and another by their *subgeneric* names, and the same word would be sometimes used in a *generic*, sometimes in a *subgeneric* sense, so that instead of a uniformity of language being adopted by zoologists, nothing but a vague and capricious uncertainty would result. If it were possible to establish a uniform system of *trinomial* nomenclature, so as always to indicate every species by its generic and subgeneric as well as by its specific name, the use of subgenera might indeed be tolerated, but such a method would be far too cumbrous and oppressive for practice, and I must therefore enter my humble protest against subgeneric names altogether. Not that I object to the subdividing large genera for convenience of reference into *defined* though *anonymous* groups; but let not these groups be designated by proper names, unless their characters be sufficiently prominent to warrant *generic* distinction.

* Collectors would double the value of their specimens if they would invariably attach to them a small label, stating at least the sex, date, and locality, and adding any other observations which they may be able to make.

nothing would be easier than to instruct those ingenious people in the art of collecting specimens. We obtain, too often indeed in a mutilated state, the gaudy *Paradisiidæ* of New Guinea, but the less attractive birds of that country, as well as of the whole Polynesian archipelago, are almost unknown. From Madagascar a few remarkable species have been occasionally sent to Europe, but the peculiarly insulated fauna of that island, partaking neither of an African nor an Asiatic character, is still very imperfectly explored. Even our own colonies of the West Indies and Honduras have been regarded only with a commercial, and not with a scientific eye, and their ornithology affords to this day—with shame be it spoken—an almost untrodden field of inquiry. Morocco, Eastern Africa, Arabia, Persia, Ceylon, the Azores, and the rocks and billows of the southern ocean, present ample materials for the future researches of the ornithologist, and will doubtless furnish many new generic and specific forms.

5. Besides the collecting of new species, the correct determination of those already described is no less important. The names and characters of species are scattered through such an infinity of works, and are often so vaguely defined, that the apparent number of known species far exceeds the real one, and much critical labour is required to reduce the nominal species to their actual limits. Having myself devoted much time to this department of ornithology, I have found that the number of synonyms is nearly threefold that of the species to which they refer, and it is important that the further growth of this evil should be checked by the publication of exact lists of species and their synonyms.

6. This vast multiplication of nominal species mainly results from the great number of scientific periodical works now issuing in all parts of the civilized world, and which it is almost impossible for any one person to consult. This is an unavoidable consequence of the great diffusion of knowledge at the present day, but the inconvenience which results from it might be much diminished if some method were adopted of centralizing the mass of scientific information which is daily poured forth. It is much to be wished that some publication like the excellent but extinct 'Bulletin des Sciences' were again established, containing abstracts of all the important matter in other scientific works; or if this were found too great an undertaking, a periodical which should merely announce the titles of the articles contained in all other scientific Journals and Transactions as they are published, would be a most useful indicator to the working naturalist. Perhaps the nearest approach towards supplying this desideratum at present, is made by the French scientific newspaper 'L'Institut,' and in Germany by Oken's 'Isis,' and Wiegmann's 'Archiv.' We shall shortly too possess an alphabetical index to all works and memoirs on zoology, through the praiseworthy efforts of Prof. Agassiz, whose gigantic undertaking, the 'Bibliographia Zoologica,' is now ready for the press.

7. The science of ornithology would be much advanced if a greater number of persons would devote themselves to the *general subject*. The majority of those who now study it, or form collections, confine themselves to the birds of their own country, under an impression that general ornithology is too wide a field for them to enter upon. They often are not aware at how small an expenditure of money or space a very large general collection may be formed. By adopting the plan first recommended by Mr. Swainson, of keeping the skins of birds in drawers, instead of mounting them in glazed cabinets, the collector may arrange many thousand specimens in a room of ordinary size, and have them at all times ready for reference and study. Or if the ornithologist considers a general collection too cumbrous, he may devote himself to the study and arrangement of particular groups, and supply

the science with valuable monographs. Such a course would be of far greater service to zoology, as well as more interesting to the student, than if he were to confine himself to the almost exhausted subject of European or British ornithology.

8. The last point which I shall notice is the prevailing want of scientific arrangement in our ornithological museums, both public and private. I have seen few collections in this country in which anything more is attempted than a general *sorting* of the specimens into their orders and families, and fewer still in which the generic and specific distinctions are indicated by systematic arrangement and uniformity of labelling. It is needless to remark how essential classification is to the scientific utility of a museum, but some excuse for the general want of it may be found in the scarcity of suitable works to serve as guides in arrangement. Now, however, by following the code of zoological nomenclature adopted by this Association (Report for 1842), and by taking as models the excellent 'Catalogues of the British Museum,' and Mr. G. R. Gray's 'Genera of Birds,' the scientific curators of museums can be no longer at a loss, and we may hope soon to see a great reform effected in the arrangement of our ornithological collections.

In concluding this sketch of the progress and prospects of Ornithology, I must apologize for many imperfections and omissions which are unavoidable in treating of so extensive a subject. A person with more time at command and more favourably circumstanced for consulting authorities, would doubtless have rendered this Report more complete, but I trust that it may be of some use in guiding the student to the sources of his information, and in pointing out the best methods of advancing this fascinating department of scientific zoology.

Report of Committee appointed to conduct Observations on Subterranean Temperature in Ireland. By THOMAS OLDHAM, *Esq.*

IN pursuance of this object thermometers were placed, in August 1843, in the deepest part of the Knockmahon Copper Mines in the County of Waterford; one being sunk three feet into the rock, and another into the lode at a depth of 774 feet from the surface. A thermometer of ordinary construction was hung in the gallery or level where these were placed, and another fixed four feet from the level of the ground at surface in shade, all protected from radiation, &c. By the zealous assistance of Mr. J. Petherick, the agent of the Mining Company of Ireland, arrangements were made that all these should be regularly read by the underground captains. It was intended to have completed an entire year's observations, but the necessity for extending the working of the mine in that part obliged the instruments to be removed in July 1844.

The readings are given in full in the tables, the necessary corrections having been made to reduce them all to the same standard.

These mines are in lat. 52° 8′ north, and the mean annual temperature at the surface calculated by the usual formula would, therefore, be 50°·026.

The general average of the thermometers at the depth of 774 feet, and the maxima and minima, were as follows:—

	Average.	Maximum.	Minimum.
	°	°	°
In air	57·176	58·5	56·25
In rock or country	57·369	58·5	56·25
In lode	57·915	58·5	57·25

being a difference in excess of the rock over the air of ·193, or nearly ·2 of a degree, and of the lode over the rock of ·546.

Taking the temperature of the rock thus determined as the general average, it shows an increase of 7°·343 Fahr. for a depth of 774 feet, or deducting 100 feet for the line of no variation, we have 7°·343 for 674 feet, or 1° for 91·82 feet.

This is a much lower rate of increase than has been noticed in general hitherto. It was found necessary in the present case to fix the instruments not far from being perpendicularly under the sea, the shaft of the mine being nearly on the edge of the cliff, which is here 70 to 75 feet high. If therefore we should allow for this difference, and consider the sea level as the surface, we shall have a depth of 600 feet corresponding to 7°·343 Fahr., or 1°=81°·74 feet, still, after making every allowance, a slower rate of increase than usually observed.

Another important circumstance which seems to be fully established by these observations, is the fact that there was a gradual though slight diminution of the temperature as the observations proceeded. Thus, if we take the average of the first half of the observations for the thermometer in air at the bottom, and compare it with the average of the last half, we find the result thus:

First half, from August to January . . .	57·613
Last half, from January to July	56·697
Difference	·916

the diminution being nearly one degree.

Similarly, the thermometer in the rock gives as an average for the first half 57·718; for the last half 57·044; the difference being ·674.

The thermometer in the lode gives,—

First half	58·000
Last half	57·675
Difference . . .	·325

a smaller difference than in the last cases; but this instrument, it should be remembered, was not fixed for four months after the others.

That this diminution was a gradually increasing one would become evident from comparing the results more in detail; but the general fact seems abundantly established, that so far from the operations of mining, the men employed, the lights, blasting, &c., having the result of increasing the temperature below, this temperature constantly and gradually decreased as these operations became more extensive.

It may be mentioned, in connection with the observations here given, that it is also the impression of the miners employed in these mines, many of whom have also worked in Cornwall, America, &c., that it is the coolest copper-mine they ever wrought in.

In addition to these observations, arrangements have been made for a similar series in other mines, where the rocks are of a different character, but as yet no results have been obtained sufficient to report to the Association.

Of the £10 granted at the last meeting of the Association for these experiments, £5 has been expended for the repairs of instruments, carriage, &c.

T. Oldham.

[To this Report was appended a register of all observations from August 7, 1843, to July 13, 1844.]

Report on the extinct Mammals of Australia, with Descriptions of certain Fossils indicative of the former Existence in that Continent of large Marsupial Representatives of the Order PACHYDERMATA.

By Prof. OWEN, *F.R.S.*

THE fossil bones discovered by Major (now Colonel Sir T. L.) Mitchell, in the ossiferous caves of Wellington Valley, and described in the Appendix to his 'Expeditions into the Interior of Australia,' established the former existence in that continent, during the period apparently corresponding with that of the deposition of our post-pliocene unstratified drift, of species of Wombat (*Phascolomys*), Potoroo (*Hypsiprymnus*), Phalanger (*Phalangista*), Kangaroo (*Macropus*), and Dasyure (*Dasyurus*); but not any of the remains were referrible to the known existing species of those genera, whilst some of the extinct species, as the *Macropus Titan* and *Macropus Atlas*, greatly exceeded in size the largest known Kangaroos*. The fossil Dasyure (*Das. laniarius*) also far surpassed in bulk any of the known Dasyures now living in Australia, and more than equalled the largest existing species (*Dasyurus ursinus*), which is confined to Van Diemen's Land. The fossil lower jaw, which, from the width of the dental interspaces, I was led to doubt, in 1838, whether to refer to the *Dasyurus laniarius* or to "some extinct marsupial carnivore of an allied but distinct species†," I have subsequently been able to identify, generically, with the *Thylacinus*, by comparison with the skull of that species,—the Hyæna of the Tasmanian colonists,—which I have lately received through the kindness of Sir John Franklin‡. In addition to the fossils thus generically allied to the peculiar marsupial Mammalia of the Australian continent and adjacent islands, I likewise detected in one specimen§ an indication of a species surpassing in size any of the others, and with characters so peculiar as to justify me in regarding it as generically distinct from all known recent or fossil Mammalia, and for which I proposed the name *Diprotodon*||, subsequently referring it to the same marsupial family as the Wombat¶.

Since the period of the examination of the fossils above alluded to, Sir Thomas Mitchell has at different times transmitted other mammalian fossils to Dr. Buckland and myself, from the plains of Darling Downs; the College of Surgeons has received from Dr. Hobson, of Melbourne, South Australia, remains of large extinct Mammalia discovered by Mr. Mayne in recent tertiary or post-pliocene deposits of the district of Melbourne; and I have been favoured by Count Strzelecki with the opportunity of examining the collection of fossils obtained by that enterprising and accomplished traveller whilst exploring the cave district of Wellington Valley in 1842.

In the notices of some of these fossils which I have communicated to the 'Annals of Natural History,' the former existence of a large Mastodontoid quadruped was first indicated** by a fossil femur; the gigantic Proboscidian being subsequently determined, by a molar tooth obtained by Count Strzelecki from a bone-cave in the interior of Australia, to have been very nearly allied to the *Mastodon angustidens*††.

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* Mitchell's 'Three Expeditions into the Interior of Australia,' 8vo, 1838, vol. ii. p. 359.

† Ib. p. 363.

‡ Entire and well-preserved bodies of the Thylacine have since been transmitted by Ronald Gunn, Esq. to the Royal College of Surgeons.

§ Mitchell, *loc. cit.*, pl. 31, figs. 1 and 2.

|| Ib. p. 362. The name has reference to the two large incisive tusks in the lower jaw, a type of dentition common to several existing marsupial genera, but displayed on a comparatively gigantic scale by the extinct quadruped in question.

¶ 'Phascolomyidæ,' Classification of Marsupialia, Zoological Transactions, vol. ii. p. 332.

** Annals of Natural History, vol. xiii., May 1843, p. 329.

†† Ib., vol. xiv. p. 268.

This is the only Australian fossil of the Mammiferous class which I have hitherto been able to refer with certainty to an extra-Australian genus.

A portion of a molar tooth presenting characters very like those of the molars of both the *Mastodon giganteus* and the *Dinotherium*, described and figured in my first memoir on the Mastodontoid femur*, I was subsequently enabled to refer, in a notice of the true Mastodon's molar, to the genus *Diprotodon.*

The present Report is designed to give additional information of the nature and affinities of the *Diprotodon*, as well as of two species of an allied but distinct genus of large Pachydermoid marsupials; such information having been derived from an examination and comparison of the series of fossils from the three distinct and remote localities in the continent of Australia above-mentioned.

Genus Diprotodon.

Species *D. australis.*

The most decisive specimen of this species consists of the anterior extremity of the right ramus of the lower jaw, exhibiting the rough articular surface of the broad and deep symphysis, the base of the large incisive tusk, the second and third molars, and the socket of the first. The third molar is the most entire; its grinding surface is produced into two high subcompressed transverse ridges, placed one before the other; there is also a ridge along both the anterior and the posterior parts of the base of the crown. The exposed commencement of the fangs is invested with a thick coating of cement; a portion of this substance also remains in the interspace between the posterior eminence and its basal ridge; the enamel is thick and presents a rugose or finely-reticulate and punctate exterior, the perforations being seen at the fractured margins to lead to smooth pits extending a little way into the enamel. The antero-posterior diameter of this tooth is two inches, the transverse diameter is one inch three lines; the extent of the three sockets of the molars is four inches five lines; they progressively diminish in size from the third to the first. The second molar is much narrower than the third, but its crown seems also, by the form of the broken surface, to have supported two principal transverse eminences and an anterior and posterior basal ridge; its antero-posterior extent is one inch and a half, its transverse diameter at the posterior division, where it is thickest, is nine lines; the coronal ridges are broken off. The first or anterior molar is lost, but its socket shows that it was implanted, like the other molars, by two fangs. The anterior part of the symphysis and crown of the large incisor are broken off; the extent from the first molar to the fractured end measures six inches three lines; the upper border of this tract manifests no trace of tooth or socket. The incisive tusk extends forwards and slightly upwards; it is subcompressed, measuring one inch and a half in the vertical diameter and nearly one inch in transverse diameter; it has a partial coating of enamel, which extends over the inferior part of the internal and the lower two-thirds of the external surface of the tusk; the enamel has the same rugose punctate outer surface as that of the molar teeth. The large size of the dental canal exposed by the posterior fracture of the ramus indicates the ample supply of vessels and nerves which ministered to the growth and nutrition of the incisive tusk; the great depth of the symphysis of the jaw gave the required strength for the operations of the tusk, and space for its support and for the lodgement of its large persistent matrix. The vertical diameter of the symphysis of the jaw anterior to the molar series is four inches. The symphysial surface, contrasted with the

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* Annals of Natural History, vol. xiii. p. 329.

molar teeth, seems enormous, much exceeding that of any Rhinoceros, and almost equalling the same part in the deep-jawed Hippopotamus; its antero-posterior extent to the fractured end of the jaw is six inches, its vertical diameter three inches, its direction is obliquely from below upwards and forwards, its upper or posterior margin nearly straight, its lower or anterior one convex; it stands out a very little way from the vertical plane of the inner surface of the ramus. The thickest part of the symphysis of the jaw does not exceed three inches, that is, at its lower part, which is convex in every direction. The surface of the bone seems to have been naturally roughened by minute vascular grooves and ridges; it has been crushed and cracked. The ridge, which doubtless formed the anterior part of the base of the coronoid process, begins to stand out below the socket of the third grinder; the smooth abraded surface at the back of the posterior talon of that tooth indicates the pressure against a contiguous tooth in the portion of jaw which has been broken away.

The symphysial portion of jaw differs in a striking degree from the corresponding part in the known existing or extinct Pachyderms, which have, like the Australian extinct Mammal, a single incisor tusk in each ramus of the lower jaw. In the young *Mastodon* the tusk is situated in a less deep, more suddenly contracted, and more produced symphysis; the symphysis of the jaw in the existing Sumatran Rhinoceros, and in the extinct *Rhin. incisivus*, is much less deep and is broader in proportion; the peculiar deflection of the symphysis in the *Dinotherium* makes it differ still more strikingly from the *Diprotodon*, in which the incisive tusks of the lower jaw extended obliquely upwards. The sudden slope of the toothless margin of the jaw anterior to the molares distinguishes the existing Proboscidians, which have, besides, a smaller anchylosed symphysis and no lower tusks.

In the proportion of the symphysial articulation to the molar teeth, I know of no quadruped that so nearly resembles the present large Australian fossil as the Wombat; but in this Marsupial that part of the ramus of the jaw is broader in proportion to its depth; in this dimension, viz. the proportion of breadth to depth of the jaw supporting the anterior molares, the Kangaroo more resembles the Diprotodon; and the molars of the Kangaroo in their double-ridged crowns are those amongst the Marsupials which most closely correspond with the molars in the present gigantic fossil.

In the general size of the tusk and jaw, in the extent of the symphysis, in the subquadrate form of the incisive tusk, and the partial disposition of enamel, the agreement between the present fossil, which was obtained from the bed of the Condamine river, west of Moreton Bay, and the corresponding fragment of jaw and tooth above-cited*, from the Wellington Valley cavern, is so close as to leave no doubt as to their generic identity. The tusk in the cavern specimen appears to be a trifle broader in proportion to its depth or vertical diameter, and a difference is indicated in the shape of the symphysial articulation; but these may be individual or sexual varieties, and at all events they do not afford decisive ground for specific separation. The original condition of the fossil from the stratum forming the bed of the Condamine river is much altered and it is heavily impregnated with mineral matter.

The next specimen, obtained by Sir T. Mitchell from the same locality and deposit as the fore-part of the jaw above described, yields an interesting indication of the affinity of the *Diprotodon* to the peculiar Order which almost exclusively represents the Mammalian class in Australia. It is a portion of the left ramus of the lower jaw of apparently the same individual *Diprotodon australis*; it includes the two fangs of the last molar teeth and the angle of

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* Mitchell, *loc. cit.*, pl. 31, figs. 1 and 2.

the jaw. This part more decidedly manifests the marsupial character by its inward inflection and by the broad flattened surface which the under part of the jaw there presents; this surface forms a right angle with the outer surface of the ramus, the lines of union being rounded off; the outer surface, which is entire to the base of the coronoid process, is slightly concave. The Elephants, Mastodons, and Tapiroid Pachyderms present the opposite or convex form of the outward surface of the jaw; the Dinotherium comes nearest, amongst the Pachyderms, to the character of the angle and base of the ascending ramus of the jaw manifested in the present fossil; which however, in the greater degree of inflection and flattening of the angle, more closely adheres to the marsupial type. The alveolar ridge is continued backwards, for the extent of two inches, in the form of a flattened platform of bone, forming an angle at its inner and posterior extremity. The thin base of the coronoid process extends along the outer border of this platform, and the entry of the dental canal is situated near the posterior end of the base of the coronoid. The condyloid process and the back part of the jaw are broken away; a great part of the thick ridge formed by the inwardly inflected angle of the jaw has also suffered fracture; but about one inch of the middle part of this characteristic structure is entire. The preserved fangs of the last molar show it to have been as large as would comport with the proportions of the molars in the preceding specimen.

The following fossils not only extend our knowledge of the dentition of the under jaw of the *Diprotodon*, but also of the range of the species over the continent of Australia; they were discovered by Mr. Patrick Mayne a few feet below the surface, during the operations of sinking a well, near Mount Macedon, in the district of Melbourne, and are noticed by Mr. Augustus F. A. Greeve, in the 'Port Phillip Patriot' of February 5th, 1844. He specifies the incisor as that "of a large animal, most probably a gigantic Wombat," and after an account of the molar teeth, thus concludes:—"But I feel assured that it is a new and most interesting genus; the discovery, in fact, of the gliriform type of the Pachydermata, the connecting link between the family which comprehends the Beaver and Rabbit with that of the Elephant, the Horse and the Hippopotamus!"

Mr. Greeve appears to have been unacquainted with my descriptions of the Australian fossils in Major Mitchell's work, or he would probably have recognised the similarity between his specimens and those which had led me to establish a new genus and to indicate its affinities, as manifesting the gliriform type of the marsupial order on a gigantic scale. A series of the specimens discovered by Mr. Mayne having been transmitted to me by my friend Dr. Hobson, I was enabled to identify them with the *Diprotodon* of the caves of Wellington Valley and of the plains near Moreton Bay, and it was with peculiar satisfaction that I afterwards perused the concurrent testimony of Mr. Greeve as to their indications of a distinct genus, and of the resemblance of the incisor to that of the Wombat, which had struck me so forcibly at the commencement of my investigation in 1837 of the fossil remains of the *Diprotodon*. The fossils from Mount Macedon are in a very different condition from those discovered in the bed of the Condamine river; they are not impregnated with mineral matter, but are extremely light and fragile, having lost all their animal matter, and consequently adhering strongly to the tongue; they are in almost the same state as the remains of the Megatherioid quadrupeds from the recent deposits forming the Pampas of Buenos Ayres.

The teeth are principally from the same under jaw, of which an outline was transmitted to me by Dr. Hobson, the original having crumbled to dust on exposure to the air. The first specimen consists of the under part of the base of the left incisive tusk of the *Diprotodon australis*; showing the line where the rugose punctate, as if worm-eaten, enamel ceases at the angle between the under and inner surfaces of the tusk, and the coat of cement covering the unenameled dentine, the smooth pulp-cavity gradually widening to the base of the tusk, is exposed to the extent of three inches. This portion of the great incisor is identical in form and structure with the specimen from the bone-cave of Wellington Valley, figured and described in Sir T. L. Mitchell's 'Expeditions into Australia,' vol. ii. p. 362, pl. 31, figs. 1 and 2, and with that from the Condamine river above described.

The next specimen is the crown and beginning of the fangs of the antepenultimate molar, right side, lower jaw, of the same *Diprotodon australis*. The form of the two transverse eminences, the summits of which had just begun to be abraded by mastication before the animal perished, is well displayed: they are more compressed than in the Tapir and Dinothere, and their lamelliform summits rise higher beyond their basal connexions than in the Kangaroo. The median connecting ridge which extends between the two transverse eminences longitudinally or in the axis of the jaw, in the molars of the Kangaroo, is very feebly indicated in the Diprotodon; the anteriorly concave curve of the summits of the transverse ridges is more regular and equable and greater than in the Tapiroid Pachyderms, the Dinothere or the Kangaroo. The cement, though thin upon the crown, is most conspicuous at the bottom of the valley between the two transverse eminences; as in the molar tooth of *Diprotodon* described in the 'Annals of Nat. Hist.' May 1843. The two fangs, the contiguous surfaces of which present the deep and wide longitudinal groove, as in the Tapiroid Pachyderms and the Kangaroo, are connected together at their base by a ridge, coated thickly with cement, and extending longitudinally between the beginnings of the opposite grooves.

The third specimen is the second molar tooth, left side, lower jaw, of the *Diprotodon australis*, from an older individual than the preceding. The anterior fang is broken off, the posterior one is preserved to the extent of one inch and a half; the crown of the tooth is entire, except where the summits of the two transverse ridges have been abraded by mastication: it demonstrates what is obscurely indicated in the corresponding molar tooth in the fragment of jaw from the Condamine river, that, besides the two principal eminences, there is a small anterior basal ridge, and a thick obtuse posterior ridge, ascending a little obliquely from the outer to the inner side of the tooth; from the anterior and posterior extremities of each basal ridge, a lower ridge extends upwards to the summit of the principal eminence; these eminences are also connected together by a short ridge at the outer and at the inner part of their basal interspace, and each of the principal eminences swells out near the middle of their interspace, indicating as it were the median longitudinal ridge which connects the two chief transverse eminences in the crown of the molar of the Kangaroo. The enamel presents the same rugose-reticulate and punctate surface as in the molars of the specimen from the Condamine, that superficial character being more conspicuous in the fore and back part of the coronal eminences than upon their outer and inner sides. The outer border of the transverse eminences is more convex than the inner one.

The fourth specimen is the third or antepenultimate molar, left side, lower jaw, of the same individual *Diprotodon australis*. Like the preceding tooth, this gives evidence of an older, and likewise a rather larger individual than the second specimen: the crown has been more worn, and shows better the depth of the interspace between the two principal ridges, the slight production of the middle of the posterior surface of the anterior ridge, and the depression on the opposite surface of the posterior ridge. The antero-posterior extent of the base of the crown of this tooth is one inch nine lines; the breadth of the crown is one inch three lines; the height of the crown one inch two lines; the length of the posterior fang was two inches when entire.

The fifth specimen is the crown of the penultimate molar, left side, lower jaw, of apparently the same individual *Diprotodon australis*. The anterior transverse ridge had just begun to be worn: the summit of the posterior ridge is entire. This is not divided into small mammilloid tubercles as in the Dinotherium, but is irregularly and minutely wrinkled as in the Tapir. In the depth of the cleft between the two transverse ridges, the teeth of the Diprotodon resemble those of the Tapir more than those of the Kangaroo; but the eminences are higher and more compressed than in either of those existing genera. In the largest existing species of Kangaroo, as the *Macropus major* and *Macropus laniger*, the lower molars have no posterior talon or basal ridge, but this is present in the still larger extinct species of Kangaroo, called *Macropus Atlas*, in which, however, it is much smaller than the anterior talon. In the Tapir the anterior talon is also larger than the posterior one, but in the Diprotodon the proportions of the two basal ridges are reversed. The reticulo-punctate markings are present at the anterior surfaces of the enamel of the transverse ridges of the molars in the Tapir, whilst in the Kangaroo and Dinothere the enamel is smooth and polished: the molars of the Diprotodon are characteristically distinguished by the rugose punctate markings in both the anterior and posterior surfaces of the transverse ridges. The breadth of the crown of the present tooth is one inch and a half, and the height of the entire posterior division is the same.

The sixth dental fossil is the anterior part of the anterior transverse eminence of the last molar tooth, left side, lower jaw, of the same *Diprotodon australis*; it measures one inch nine lines across the base, and diminishes in breadth more gradually towards the summit than in the preceding tooth. The summit of this eminence had just begun to be worn by mastication; the pulp cavity is continued into the basal third of the crown.

These specimens which show the termination of the molar series, with the anterior part of the jaw from the Condamine river containing the commencement of the molar series, demonstrate the entire number of teeth in the lower jaw which characterizes the genus *Diprotodon*, viz. one incisor and five molars on each side. In this formula the great Pachydermoid marsupial resembled the Wombat, the Koala, the Potoroo, and the Kangaroo, although it is rare to see the total number of true molar teeth at one time in the larger species of *Macropus*. The lower incisors of the Koala in the subcompressed subquadrate form of their implanted base most resemble in form those of the Diprotodon, but the exserted crowns, like those of the Kangaroos, have an entire covering of enamel which does not extend upon the inserted fang. In the partial covering of the whole extent of the inserted base of the tusk of the Diprotodon, we perceive a greater resemblance to the scalpriform incisor of the Wombat; and every analogy teaches that the exposed part of the tusk of the Diprotodon must have had the same extent of enamel-coating as the inserted base. The Diprotodon, however, departs widely from the genus *Phascolomys* in the divided base and in the shape of the crown of its molar teeth: in these more essential parts of the dental system it approximates *Macropus* more closely than any other known Marsupial genus; yet the double transverse-ridged type of molar teeth is manifested by so many genera of recent and extinct Mammalia[*] of very different forms and organization that little could be inferred as to the coexistence of the proportions of the Kangaroo

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[*] *Tapirus, Lophiodon, Dinotherium, Manatus.*

with such molar teeth in the case of the great Australian Pachydermoid. I proceed, therefore, to notice two of the most complete bones which were discovered in the same stratum and locality as the portions of the lower jaw of the Diprotodon from the bed of the Condamine river, and which, from their agreement in size with those mandibular fragments, belong very probably to the same species; they have undergone precisely the same mineral change.

The first of these is the body of a dorsal vertebra of unquestionably a mammalian quadruped of the size of the *Diprotodon australis*. It measures two inches three lines in antero-posterior diameter, three inches in vertical diameter, and four inches nine lines in transverse diameter. Both articular extremities are flat, the epiphysial plates are anchylosed; but where they are broken away, the radiating rough lines, characteristic of the epiphysial surface, indicate that the union was tardy, and had been recently effected before the animal perished. This vertebra differs by its compressed form and the flattening of the articular ends from the dorsal vertebræ of the ordinary placental Pachyderms, but resembles in these characters the dorsal vertebræ of the Proboscidians (*Elephas*, *Mastodon*). In these, however, the breadth of the vertebral body is not so great as in the fossil. From the Cetacean vertebræ the present fossil is distinguished by the large concave articular surface at the upper and anterior part of the side of the body for the reception of part of the head of a rib: this costal surface, which is not quite entire, appears to have been about an inch and a half in diameter. The neurapophyses are anchylosed to the centrum, but the internal margins of their expanded bases are definable, and have been separated by a tract, rather less than an inch in breadth, of the upper surface of the centrum. At the middle of this surface there is a deep transversely oblong depression: a similar depression is present in some of the dorsal vertebræ, and in the anchylosed lumbar vertebra of the Mylodon; but the bodies of the dorsal vertebræ, in all the great extinct *Bruta*, are longer and narrower in proportion to their breadth than in the present fossil. The upper and posterior margin is here indented on each side by the dorsal nerve, which, in the monotrematous *Echidna*, perforates the base of the neurapophyses; otherwise the body of the dorsal vertebra in that Implacental corresponds in its proportions, and in the depression on the upper part of the body, with the present fossil. In the Kangaroo the upper surface of the body of the dorsal and lumbar vertebra is perforated by two vascular canals, which pass down vertically and open below by a single or double outlet. In the Wombat the middle of the upper surface of the bodies of the dorsal and lumbar vertebra exhibits a single large and deep depression, which, in the dorsal vertebræ, has no inferior outlet, and in this character they closely resemble the present fossil. The dorsal vertebræ of the Wombat are however longer in proportion to their breadth. Thus the present mutilated vertebra alone would support the conclusion, that there had formerly existed in Australia a mammiferous quadruped, superior to the Rhinoceros in bulk, and distinct from any known species of corresponding size; and it is interesting to find one well-marked character in it, viz. the median excavation on the upper part of the body, repeated by one of the larger of the existing Marsupialia.

The second fossil speaks more decisively both for the Marsupial nature of the species to which it belonged and as to its more immediate affinities in that Order. It is the right os calcis, which measures six inches in length and five inches and a half in breadth, presents two large articular surfaces at right angles to each other upon its upper and anterior part, has a short calcaneal or posterior process, which is broad, depressed and bent upwards, and a short thick obtuse process directed downwards from the internal and under part of the bone. The inner and upper articular surface is semicircular, very slightly concave, with a small part continued down or sinking from the middle of its outer margin at a rather open angle, towards the outer or cuboidal facet: this is a larger and more deeply concave surface than the preceding, with a well-defined margin; it is situated on the outer side, not anterior to the astragalar surface. The astragalar surface is separated from the calcaneal and inferior tuberosity by a wide and moderately deep tendinal groove, analogous to that along which the tendon of the *flexor longus pollicis* glides in Man. The base of the calcaneal process, which is united to the posterior part of the cuboidal concavity, is perforated by a short canal, half an inch wide, continued downwards and forwards, and leading to a wider tendinal groove, which impresses the inferior surface of the part of the bone supporting the cuboidal facet. The plane of the posterior part of the calcaneal projection is at right angles with the inferior rough surface of the bone.

The characters of the present fossil calcaneum, as above briefly defined, are unique. The size of the bone leads us first to compare it with the calcaneum of the Elephant or Mastodon; but here we find two broad and flat astragalar surfaces on the upper part of the bone, and a small and very slightly concave surface anteriorly; there is moreover no perforation for a peroneal tendon. The same absence of such a perforation, and the different proportion and relative position of the cuboidal facet, distinguish at a glance the calcaneum in all the ordinary Pachyderms from the present fossil. The calcaneum of the *Mylodon robustus* is perforated at its outer part for the tendon of the peroneus longus as it is in the present fossil; it likewise has a stout tuberosity projecting from its under surface, but the calcaneal process is much larger, and is continued more directly backwards. The cuboidal facet in the Mylodon is much smaller and shallower than in the present fossil, and is not only placed anterior to the astragalar surface, but is continuous with it. Not to dwell on the differences which the Comparative Anatomist must have immediately perceived from the description of the present most remarkable bone in the corresponding one of the *Ruminantia*, the *Quadrumana*, the *Carnivora* and *Rodentia*, I proceed at once to state that it is only in the equipedal Marsupialia, and more especially in the Koala and Wombat, that we find the articular surfaces of the calcaneum two in number and of the same general form, proportions and relative position as in the fossil under consideration: the nearly flat internal and superior astragalar surface is, however, proportionally narrower in the Wombat; its outer depressed angle is shallower; the calcaneal projection is directed downwards and inwards; the strong peroneal tendon indents the outer side of the calcaneum with a groove, but does not perforate the bone. The calcaneum of the Kangaroo and Potoroo has a totally different form from the fossil: in these leaping Marsupialia the heel is subcompressed and much elongated; the astragalar surface is divided into two small distinct parts; the cuboidal facet is anterior, and convex vertically, &c. In conclusion, it may be stated that the large fossil calcaneum here described combines the essential characters of that of the Wombat with some features of that of the Mylodon and Mastodon, and others which are peculiar to itself: the single broad astragalar surface with its external depressed portion coincides with the characters of the large fossil astragalus subsequently to be described; though the different form of the astragalar surface appears to show the present calcaneum to have belonged to a distinct species of pachydermoid Marsupial.

That a large quadruped, whose nature and affinities are expressed by the above epithet, formerly inhabited Australia, the characters of the present os calcis would alone have rendered highly probable; and since the same conclusions are deducible from the portions of jaw above described, which correspond in proportional size, mineralized condition, locality and stratum, with the present calcaneum, it is highly probable that they all belong to the *Diprotodon australis*, a species whose affinities to the Wombat were perceived by the characters of the single tusk and fragment of jaw first transmitted from the caves of Wellington Valley.

Genus NOTOTHERIUM.

Species 1, *N. inerme.*

I next proceed to notice a second small but instructive series of fossils, including portions of lower jaws, which, by the total absence of incisors, indicate a distinct genus of pachydermoid Mammals, with the same kind and amount of evidence of its marsupial affinities: the principal fossil is the almost entire right ramus of the lower jaw.

The dentition in this jaw consists of molar teeth exclusively, four in number, which increase in size as they approach the posterior part of the series: a small portion of the anterior end of the symphysis is broken away, but there is no trace there of the socket of any tooth, and it is too contracted to have supported any tusk or defensive incisor. The length of the jaw is eleven inches: the molar series, which commences one inch in advance of the posterior border of the symphysis, is six inches in extent: each tooth is implanted by two strong and long conical fangs, the hindermost being the largest, and both being longitudinally grooved upon the side turned to each other. The first tooth is wanting, and the crowns of the rest are broken away: the base of the third remains, and gives an indication of a middle transverse valley, which most probably separated two transverse eminences. This jaw resembles that of the proboscidian Pachyderms in the shortness of the horizontal ramus; and of the Elephant more particularly, in the rounding off of the angle, and in the convex curvature of the lower border of the jaw from the condyle to the symphysis, and also in the smaller vertical diameter of the symphysis, and the more pointed form of that part. It resembles the jaw of the Elephant in the form, extent and position of the base of the coronoid process, but it differs from the Elephant in the concavity on the inner side of the posterior half of the ramus of the jaw, which is formed by an inward inflection of the angle: this concavity extends forwards beneath the sockets of the two last molar teeth. It differs from the lower jaw of the Elephant in the greater flatness of the outer part of the angle of the jaw, in which respect it more resembles the Mastodon. In the extent of the angle of the jaw it is intermediate between the Mastodon and Elephant. It differs from both in the inward bending of that angle, which is remarkable for the great longitudinal extent along which the inflection takes place: most of the inflected angle has been broken away, but enough remains to demonstrate a most instructive and interesting correspondence between the present fossil and the characteristically modified lower jaw in the marsupial animals. In pursuing the comparison of the Australian pachydermal fossil with the Mastodon and Elephant, we may next observe that the alveolar process on the inner side of the base of the coronoid, behind the last molar, is as well developed as in the Mastodon: a similar angular production of this part exists, however, in the Wombat and Kangaroo. The vertical extent of the outer concavity of the coronoid process is greater in the Australian fossil than in the jaw of the Mastodon, and is less clearly defined below. The dental canal commences by a foramen penetrating the ridge which leads from the condyle to the post-molar process, and apparently just below the condyle, as in the Elephant, but it is relatively much smaller: it does not communicate with any canal leading to the outer surface of the ascending ramus, as in the Wombat and Kangaroo; but this external opening is not present in all Marsupials. The anterior outlet of the dental canal is smaller than in the Mastodon, and being placed more forwards, resembles that in the Elephant. The number, and apparently the form of the teeth, approximate the Australian Pachyderm more closely to the Mastodon than to the Elephant, but the equal size of the last and penultimate teeth, which had the same number of divisions of the crown, are points in which the extinct species represented by the present jaw still more nearly resembled the Diprotodon, the Tapir and the Kangaroo.

In its general shape the fossil jaw in question differs widely from all existing Marsupials and all known ordinary Pachyderms, and in the chief of these differences it resembles the lower jaw of the Proboscidians. It resembles these however, in common with the Wombat, in the forward slope and curvature of the posterior margin of the ascending ramus extending from the condyle to the angle of the jaw, in the inward production of the post-molar process, in the position of the base of the coronoid process exterior to the hinder molar, in the thickness of the horizontal ramus, as compared with its length, and the convexity of its outer surface; and it also resembles the Proboscidians, in common with the Kangaroo, in the small number of the grinding teeth. From the lower jaw of the Kangaroo and Wombat the present fossil differs in the absence of the deep excavation on the outer side of the ascending ramus, which, in those Marsupials, leads to a perforation in the base of that part of the jaw; and it also differs in the inferior depth of the inner concavity, and the inferior extent of the inward production of the angle of the jaw, besides the more important difference in the absence of the large incisor tooth. From the jaw of the Diprotodon, the present fossil differs in the much smaller vertical extent of the symphysis, and in the convexity of the jaw at its outer and anterior part, and more essentially in the absence of the incisive tusk and its socket; but it must have closely resembled the Diprotodon in the general form and proportions of the molar teeth. On these grounds I propose to indicate the genus of the fossil Mammal to which the above-described lower jaw belonged by the name of *Nototherium*, and the species as *inerme*, from the absence of the incisive tusks.

Species 2, *N. Mitchelli.*

The posterior half of the ramus of the lower jaw of a second species of *Nototherium*, wanting the condyloid and the upper part of the coronoid processes, and containing the last two molar teeth; the crowns of these teeth are much fractured, but demonstrate that they were divided into two principal transverse ridges. The antero-posterior extent of both teeth together is three inches three lines, the last molar being two lines longer in this dimension than the penultimate one: its transverse breadth is one inch two lines. The dentine of the crown is encased in a sheath of enamel of nearly one line in thickness, with a smooth and polished surface, impressed at the outer part and near the base of the tooth, where the enamel is principally preserved, with fine parallel and nearly horizontal transverse lines.

Part of the abraded surface of both transverse ridges is preserved in the penultimate grinder, showing that they had been more than half worn away by mastication at the period when the animal perished. The smooth and polished exterior of the enamel covering the anterior part of the posterior eminence presents a striking contrast to the reticulo-punctate character of the enamel, at the corresponding part of the molar in the Diprotodon, which in the general form and proportion of this part of the jaw so closely agrees with the present fossil. The *Diprotodon australis* exceeded, however, both species of *Nototherium* in size, so far as can be judged by the lower jaw and teeth.

The penultimate and last molar teeth very little exceed in any comparable dimension those of the last described half-jaw, which from the length of the fangs were as completely developed, and belonged therefore to an equally mature animal; but the depth of the jaw below the middle of the penultimate molar in the present fossil is three inches three lines, and in the entire half-jaw it is only two inches nine lines; the thickest part of the jaw beneath the same molar in that jaw is two inches three lines, but in the present fragment it is only one inch eleven lines. In the entire half-jaw the external wall of the alveolar process immediately swells out to form this thick part of the ramus, but in the present fragment it maintains its thinness for an inch below the margin of the socket, and the outer part of the jaw is slightly concave here, before it begins to swell into and form the bold convexity which is continued to the thick inferior border of the jaw. This difference in the shape, as well as the size of the jaw, bespeaks at least a specific distinction from the jaw referred to *Nototherium inerme*. But a more marked distinctive character in the present fossil is afforded by the relative position of the last molar tooth, which is in advance of the origin or base of the coronoid process instead of being internal to and hidden by that part when the jaw is viewed from the outer side, as in the half-jaw. The outer surface of the anterior part of the base of the coronoid appears, by a fracture there, to have projected outwards further in the present specimen than in the half-jaw.

The important marsupial character afforded by the inward bending of the angle of the jaw is well-manifested by the present specimen, in which the angle is entire; it is thick and obtuse, and though slightly inflected in comparison with the same part in the Wombat or Kangaroo, it bounds a well-marked concavity which extends forwards to run parallel with the interspace between the last and penultimate molars; the regularity of the convex line extending from the posterior part of the ascending ramus to the lower border of the jaw is interrupted by a slightly produced obtuse prominence at the middle of the inflected angle. The post-molar part of the alveolar process forms a broad platform on the inner side of the base of the coronoid, and is defined by a well-marked angle at its inner and posterior part, in which it resembles both the lower jaw of the proboscidian Pachyderms and that of the Wombat. The entry of the dental canal is situated as in the *Diprotodon australis* and the *Nototherium inerme*. The coronoid process has the same extensive antero-posterior origin, and the same thinness as in the half-jaw, but it is rather more concave externally. Both the half-jaw and the present specimen are from the alluvial or newer tertiary deposits in the bed of a tributary of the Condamine river, west of Moreton Bay, Australia; they are mineralized, but of a deeper ferruginous colour than the fossils of the *Diprotodon*.

An astragalus of the same colour and mineral condition, and from the same locality as the preceding specimens, belongs also more probably to the *Nototherium* than to the *Diprotodon*, on account of its somewhat smaller size than the calcaneum above described. The peculiarities of this astragalus will be obvious to the Comparative Anatomist from the following description:—It is a broad, subdepressed and subtriangular bone, the angles being rounded off, especially the anterior one; the upper or tibial surface is quadrate, concave from side to side, in a less degree convex from before backward; a ridge extending in this direction divides the tibial from the fibular surface, which slopes outwards at a very open angle and maintains a nearly horizontal aspect, presenting an oblong trochlea for the support of the fibula, shallower, and one-third smaller than that for the tibia. The tibial articular surface is not continued upon the inner side of the astragalus, but its anterior and internal angle, which becomes convex in every direction, is immediately continued into the anterior scaphoidal convexity, which sweeps round a deep and rough depression, dividing the outer and anterior part of the tibial trochlea from the corresponding half of the scaphoidal convexity; this has the greatest vertical extent at its inner part, where it is separated by a narrow, rough transverse channel from the part which rested upon the os calcis. The calcaneal surface is single, and covers almost the whole of the under part of the astragalus; the greatest proportion of it is flat and reniform, an angular tuberosity or process being continued from the concave margin, where the pelvis of the kidney, to pursue the comparison, would be situated. This process must have been received into a corresponding depression at the outer part of the articular surface upon the calcaneum. On the inner margin of the flat calcaneal surface, opposite the tuberosity, a small triangular flattened surface is continued upwards upon the inner and posterior side of the astragalus, and nearly touches the inner and posterior angle of the tibial trochlea.

The length of this fossil astragalus is four inches eight lines, its breadth is three inches five lines, its depth (at the base of the scaphoidal convexity) is two inches and a half.

We look in vain amongst the Pachyderms, with astragali of corresponding dimensions, for the uniform and prominent convexity of the anterior articulation, for its continuation with the tibial trochlea, and for the single and uninterrupted calcaneal tract on the lower surface of the bone. The Proboscidians, which approach nearest the present fossil in the depressed form of the astragalus and the flattening of the calcaneal articulation, have that articulation divided into two surfaces by a deep and rough groove; the scaphoidal surface is likewise similarly divided from the tibial trochlea; and no Pachyderm has the upper articular surface of the astragalus traversed by an antero-posterior or longitudinal ridge, dividing it from an almost horizontal facet for the support of the end of the fibula.

The peculiar form of the astragalus in the Ruminants, and especially the trochlear character of the anterior scapho-cuboidal surface, place it beyond the pale of comparison. In all the placental Carnivora the scaphoidal convexity is pretty uniform, and occupies the anterior extremity of the astragalus, as in Man and Quadrumana; but it is more produced in the Carnivora and supported on a longer neck, which is also more oblique than in the Quadrumana, where the astragalus already begins to recede in this character from the Human type. In the Seals the upper surface of the astragalus somewhat resembles the present fossil in the meeting of the tibial and fibular facets at an obtuse angle formed by a longitudinal rising, but the fibular surface is rather the wider of the two, and the tibial one is divided by a broad rough tract from the scaphoidal prominence; but in addition to this anterior production of the bone there is also another process from its posterior part, which, as Cuvier remarks, gives the astragalus of the Seal the aspect of a calcaneum. In some of the remarkable peculiarities which the astragalus presents in the order *Bruta* it approaches the Australian fossil under consideration: in the Mylodon, for example, where the surface for the calcaneum is single and undivided. But in this great extinct leaf-eating quadruped the calcaneal facet is continued into the navicular facet, which, on the other hand, is separated by a rough tract from the tibial articulation, as in all the Edentata, recent and fossil. The latter character likewise distinguishes the astragalus of the Rodentia from the fossil astragalus under consideration.

In the Ornithorhynchus the astragalus has a deep depression on its inner side for the reception of the incurved malleolus of the tibia, and in both the Ornithorhynchus and Echidna the tibial surface is more convex than in the present fossil.

Amongst the existing Marsupialia, the astragalus in the largest herbivorous species, viz. the Kangaroo, offers very great differences from the present Australian fossil; the broad and shallow trochlea for the tibia is continued upon the inner side of the bone into a cavity which receives the internal malleolus, whilst the fibular facet is long and narrow, and situated almost vertically upon the outer side of the bone. The scaphoidal surface is unusually small, convex only in the vertical direction, and divided by a vertical ridge into two surfaces, the outer one being applied to the os calcis. The inferior and proper calcaneal articulation is divided into two small distinct surfaces, the outer one concave the inner one concavo-convex.

Amongst the pedimanous and gradatorial marsupials, and more especially in the Wombat, we at length find a form of astragalus which repeats most closely the characters of the extraordinary fossil under consideration; in the astragalus of the Wombat the fibular facet, of a subtriangular form, almost as broad as it is long, slightly slopes at a very open angle from the ridge which divides it from the tibial surface; this surface, gently concave from side to side, and more gently convex from behind forwards, repeats the more striking character of being directly continued by its inner and anterior angle with the large and transversely extended convexity for the os scaphoides. The calcaneal surface below is single and continued uninterruptedly from the back to the fore-part of the outer half of the under surface, and its outermost part is produced into an angle, which is received into a depression at the outer side of the upper articular surface of the calcaneum. Thus all the essential characters of the fossil are repeated in the astragalus of the Wombat. The differences are of minor import, but are sufficiently recognizable; in the Wombat, for instance, the single calcaneal surface is directly continued into the cuboido-scaphoidal convexity instead of being separated from it, by a narrow rough tract, as in the fossil; the calcaneal surface is also narrower than in the fossil, and the outer angle is less produced: the division of the tibial trochlea for the inner malleolus is better defined in the Wombat, and the depression, round which sweeps the continuous smooth surface between the tibial and scaphoid surfaces, is less deep in the Wombat; the scaphoidal convexity is also less developed in the vertical direction in the Wombat.

We thus find that the great fossil astragalus from Australia, viewed in reference to the general characters of that bone in the Mammalian class, offers remarkable peculiarities; and we further find that these are exclusively and very closely repeated in certain Australian genera of *Marsupialia*, and especially in the bulkiest of the existing vegetable feeders which are not saltatorial. The inference can hardly be resisted, that the rest of the essential peculiarities of the marsupial organization were likewise present in that still more bulky quadruped of which the fossil under consideration once formed part.

In the Kangaroo and the smaller leaping Marsupials the fibula is disproportionately slender and immoveably attached or anchylosed to the tibia, reminding one of the Ruminant type of organization; it sustains little of the superincumbent weight, and has no resting-place upon the astragalus, the outer malleolus being simply applied to the vertical outer surface of that bone. The broad and nearly horizontal surface in the present fossil clearly bespeaks the existence in the same animal of a fibula which must have almost equalled the tibia in size at its distal end, and have taken as large a share in the formation of the ankle-joint as it does in the Wombat. We may in like manner infer that the tibia and fibula were similarly connected together, and, coupling this with the ball and socket joint between the scaphoid and astragalus, we may conclude that the foot of the great extinct Marsupial possessed that degree of rotatory movement, which, as enjoyed by the Wombat, is so closely analogous to the pronation and supination of the hand. We finally derive from the well-marked marsupial modifications of the present fossil astragalus a corroboration of the inferences, as to the former existence in Australia of a marsupial vegetable feeder as large as the Rhinoceros, which have been deduced from the inflected angle and other characters of the jaw of the *Diprotodon* and the *Nototherium*, and from the fossil calcaneum which has been referred to the *Diprotodon*. The present bone closely agrees in all its marsupial modifications with that calcaneum, but the single flat surface which articulated with the calcaneum is longer in proportion to its breadth. From this circumstance, and the close agreement in colour and general condition which the present astragalus has with the jaw of the *Nototherium*, as well as its somewhat smaller size in proportion to the calcaneum, I have referred it provisionally, as before observed, to the *Nototherium*; but, for demonstration, further discoveries will be required of parts of the skeleton so associated as to justify the inference that they had belonged to one individual.

Sir Thomas Mitchell has transmitted, from the pliocene or post-pliocene deposits near Moreton Bay, in addition to the remains of the large and very remarkable quadrupeds above-described, several fossils referable to the large extinct Kangaroos called *Macropus Atlas* and *Macropus Titan*, which species were originally recognised by the fossils from the ossiferous caves of Wellington Valley. The posterior molars in the upper jaw-bone of the *Macropus Titan* show the more distinct and stronger posterior basal ridge and the more complex form of the median longitudinal buttress connecting the two chief transverse eminences, which in like manner distinguished the cave fossils of the same extinct species from the *Macropus major* and *Macropus laniger*, the largest existing species of Kangaroo.

The posterior molar teeth in a fossil lower jaw of the *Macropus Titan*, from the same deposits near Moreton Bay, manifest, with the cave specimens, the same difference from both the *Macropus Atlas* and the largest existing species of Kangaroo, in the greater antero-posterior extent of the anterior basal ridge, and from the *Macropus Atlas* also, in the greater antero-posterior extent of the base of the two principal transverse eminences of the crown, and in the absence in these molar teeth of the posterior talon. The maxillary fossils of the *Macropus Atlas*, from the same pliocene or post-pliocene deposit near Moreton Bay, in like manner agreed in size and distinctive characters with the spelæan fossils. Remains of the same extinct species of gigantic Kangaroos were also associated with the *Diprotodon* in the deposits of the district of Melbourne.

Since therefore the Mammalian fossils of the pliocene, post-pliocene, or diluvial period are already shown to be widely distributed over Australia, and appear, from the numerous specimens obtained by three or four collectors within a few years, to be as abundant in the superficial deposits and caves of Australia as are the analogous fossil remains in the corresponding formations and caves of Europe, Asia and both Americas, we may hope soon to be in possession of a body of evidence which will establish the law of geographical distribution of extinct Mammalia, as satisfactorily in regard to Australasia as it seems now capable of being determined in regard to the larger continents of the globe.

When the comparison of the extinct Mammalia of the pliocene and post-pliocene epochs with the existing species in the same locality is restricted to the Fauna of a limited space, especially an insular one like Great Britain, the discrepancy between such extinct and existing groups of Mammalia appears to be extreme. Of the smaller quadrupeds, it is true, we still retain the Bat, the Shrew, the Mole, the Badger, the Fox, the Wild Cat, the Otter, the Weasel, the Pole-cat, the Voles, the Hare and Rabbit, the Roe and Red-deer: the Beaver, the Bear and the Wolf have also existed here within the historic period: but only in menageries can we see, in our island, the living representatives of those extinct Elephants, Rhinoceroses, Tigers, Bears, Hyænas, or diminutive tailless Hares (*Lagomys*), which formerly roamed at large over the land. But if we regard Great Britain in connection with the rest of Europe, and extend our view of the geographical distribution of extinct Mammals beyond the limits of the continents of geography,—and it needs but a glance at the map to detect the artificial character of the line which divides Europe from Asia,—we shall then find a close and interesting correspondence between the extinct Mammalian Fauna of the latest geological periods and that of the present day. The very fact of the newer pliocene Mammalian Fauna of England being almost as rich in generic and specific forms as that of Europe, leads us to infer that the intersecting branch of the ocean which now divides this island from the continent did not then exist as a barrier to the migration of the Mastodons, Mammoths, Rhinoceroses, Hippopotamuses, Bisons, Horses, Tigers, Hyænas, Bears, &c., which have left such abundant traces of their former existence in the superficial unstratified deposits and caves of Great Britain*. Now, in the Europæo-Asiatic expanse of dry land, species continue to exist of nearly all those genera which are represented by pliocene and post-pliocene Mammalian fossils of the same natural continent and of the immediately adjacent island of Great Britain. The Bear has its haunts in both Europe and Asia; the Beaver of the Rhone and Danube represents the great Trogontherium; the Lagomys and the Tiger exist on both sides of the Himalayan mountain chain; the Hyæna ranges through Syria and Hindostan; the Bactrian Camel typifies the huge *Merycotherium* of the Siberian drift; the Elephant and Rhinoceros are still represented in Asia, though now confined to the south of the Himalayas. The more extraordinary extinct forms of *Mammalia* called *Elasmotherium* and *Sivatherium*, have their nearest pachydermal and ruminant analogues now existing in the same continent to which those fossils are peculiar. Cuvier places the Elasmothere between the Horse and Rhinoceros: the existing four-horned Antelopes, like their gigantic extinct analogue, are peculiar to India.

The Mediterranean and Red Seas constitute a less artificial boundary between Africa and the Europæo-Asiatic continent, than that which, on our maps, divides Europe from Asia; yet those narrow seas form a slight demarcation as compared with the vast oceans which divide the old from the new worlds of the geographer, or these from the Australian continents. The continuity of Africa with Asia is still, indeed, preserved by a narrow isthmus, near to which, within the historical period, the Hippopotamus descended, venturing down the Nile, according to Herodotus, almost to its mouth. May it not be regarded as part of the same general concordance of geographical distribution, that the genus *Hippopotamus*, extinct in England, in Europe and in Asia†, should continue to be represented in Africa and in none of the

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* See Report of British Fossil Mammalia, Trans. British Association, 1842 and 1843. In the present comparison, I purposely limit myself to the most recent of the tertiary epochs.

† Marsden, in his 'History of Sumatra,' mentions a species of Hippopotamus as still existing in the Sunda Isles; but this has much need of confirmation: the fossil sub-genus of Hippopotamus (*Hexaprotodon* of Cautley and Falconer) gives a new stimulus, however, to the inquiry after the Hippopotamus or Succatyro of the Indian Archipelago.

remoter continents of the earth?—Africa also having its Hyæna, its Elephant, its Rhinoceroses, and its great feline Carnivores. The discovery of extinct species of *Camelopardalis* in both Europe and Asia, of which genus the sole existing representative is now, like the Hippopotamus, confined to Africa, adds to the propriety of regarding the three continuous continental divisions of the Old World as forming, in respect to the geographical distribution of pliocene, post-pliocene and recent Mammalia, one great natural province. The only large Edentate animal (*Pangolin gigantesque*, Cuvier, *Macrotherium*, Lartet) hitherto found in the tertiary deposits of Europe, but in those of an earlier period (older pliocene or miocene) than the deposits to whose mammalian fossils the present comparison more immediately refers, manifests its nearest affinities to the genus *Manis*, which is exclusively Asiatic and African.

Extending our comparison between the existing and the latest of the extinct series of Mammalia to the continent of South America, it may be first remarked, that with the exception of some of the carnivorous and Cervine species, no representatives of the above-cited mammalian genera of the Old World of the geographer have yet been found in South America. Buffon[*] long since enunciated this generalization with regard to the existing species and genera of Mammalia; it is almost equally true in respect of the fossil. Not a relic of an Elephant, a Rhinoceros, a Hippopotamus, a Bison, a Hyæna[†], or a Lagomys, has yet been detected in the caves or the more recent tertiary deposits of South America. On the contrary, most of the fossil Mammalia from those formations are as distinct from the Europæo-Asiatic forms, as they are closely allied to the peculiarly South American existing genera of Mammalia.

The genera *Equus*, *Tapirus*, and the still more ubiquitous *Mastodon*, form the chief, if not sole exceptions. The representation of *Equus*, during the pliocene period by distinct species in Asia (*E. primigenius*) and in South America (*E. curvidens*), is analogous to the geographical distribution of the species of *Tapirus* at the present day. Fossil Tapirs have been found both in Europe and in South America.

Pangolins still exist in Asia and in Africa, and, as we have seen, a gigantic extinct species of Manis has been found in the middle tertiary beds of Europe, but not a trace of a scaly Anteater, recent or extinct, has been discovered in South America, where the Edentate order is so richly represented by other generic and specific forms.

South America alone is now inhabited by species of Sloth, of Armadillo, of Cavy, Aguti, Ctenomys, and platyrrhine Monkey, and no fossil remains of a quadruped referable to any of these genera have yet been discovered in Europe, Asia or Africa. The types of *Bradypus* and *Dasypus* were, however, richly represented by diversified and gigantic specific forms in South America, during the geological periods immediately preceding the present; and fossil remains of extinct species of *Cavia*, *Cœlogenys*, *Ctenomys*, and *Cebus*, have hitherto been detected exclusively in the continent where these genera still as exclusively exist. *Auchenia* more remotely typifies *Macrauchenia*. Mr. Waterhouse informs me that the murine fossils in the rich collection of remains from Brazilian caverns, lately received at the British Museum, all belong to the genus *Hesperomys*, the aboriginal living representative

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[*] Cited by Lyell in the Principles of Geology, 1837, vol. iii. p. 27.

[†] Dr. Lund (Danish Transactions, Œrsted, Kiöbenh, 1842, p. 16.) discovered the remains of an extinct Carnivore in a Brazilian cavern, which he at first announced as a species of *Hyæna*, but he has since recognised very distinctive dental characters, and refers it to a new genus, which he calls *Smilodon*: from the figures which he has given of the canine and incisor teeth it seems to belong to the same genus (*Machairodus*) as the so-called *Ursus cultridens* of Europe, and this is certainly the case with portions of the skull, lower jaw and teeth, since discovered in the Pampas of Buenos Ayres, and now in the British Museum.

of the *Muridæ* in South America; and that not one fossil is referable to a true Old World *Mus*, though numbers of the common Rat and Mouse have been imported into South America since its discovery by Europeans. With regard to the Sloths and Armadillos, they now seem, after the rich harvest of bulky Glyptodons, Mylodons, Pachytheriums, and the more gigantic Megatherioid species, to be the last remnants of a Mammalian Fauna which once almost equalled in the size and number of its species that of the Europæo-Asiatic expanse, and was as peculiarly characteristic of the remote continent in which almost all its representatives have been entombed.

In North America the most abundant Mammalian fossils of the corresponding recent geological epoch belong to a species of *Mastodon* (*M. giganteus*) peculiar to that continent. Since, however, North America borders closely upon Asia at its northern basis, and is connected by its opposite apex with South America, it perfectly accords with the analogies of the geographical relations of the last-extirpated series of Mammals of the Old World that the Asiatic Mammoth and the South American Megatherium should have migrated from opposite extremes, and have met in the temperate latitudes of North America, where, however, their remains are much more scanty than in their own proper provinces.

Australia at length begins to yield evidence of an analogous correspondence between its latest extinct and its present aboriginal Mammalian Fauna, which is the more interesting on account of the very peculiar organization of most of the native quadrupeds of that division of the globe. That the Marsupialia form one great natural group is now generally admitted by zoologists; the representatives in that group of many of the orders of the more extensive placental sub-class of the Mammalia of the larger continents have also been recognised in the existing genera and species:—the Dasyures, for example, play the parts of the *Carnivora*, the Bandicoot of the *Insectivora*, the Phalangers of the *Quadrumana*, the Wombat of the *Rodentia*, and the Kangaroos, in a remoter degree, that of the *Ruminantia*. The first collection of Mammalian fossils from the ossiferous caves of Australia brought to light the former existence on that continent of larger species of the same peculiar marsupial genera:—some, as the *Thylacine*, and the Dasyurine sub-genus represented by the *Das. ursinus*, are now extinct on the Australian continent, but still exist on the adjacent island of Tasmania; the rest being Wombats, Phalangers, Potoroos and Kangaroos, the latter of portentous stature. Subsequently, and after a brief interval, we obtain a knowledge of the former existence of a type of the marsupial group which represented the Pachyderms of the larger continents, and which seems now to have disappeared from the face of the Australasian earth.

I cannot conclude without adverting to the singular exception which the Mastodon forms to that continental localization, not only of existing, but of pliocene and post-pliocene extinct genera of Mammalia above briefly dwelt upon. The solitary character of the exception helps rather to establish the generalizations, at least I know of no other extinct genus of Mammal which was so cosmopolitan as the Mastodon: it was represented by species, for the most part very closely allied, if actually distinct, in Europe, in Asia, in North and South America, and in Australia; it is the only aboriginal genus of quadruped in that continent which was represented by other species in other parts of the world.

The most remarkable local existing Fauna, in regard to terrestrial vertebrated animals, is that of the islands of New Zealand, with which geologists have been made familiar by Mr. Lyell's indication of its close analogy with the state of animal life during the period of the Wealden formation*. The only indigenous terrestrial Mammalian quadruped hitherto discovered in New Zealand is a small rat. The most peculiar representative of the warm-blooded classes is the *Apteryx*. It is the smallest known species of the Struthious or wingless order of Birds, has the feeblest rudiments of the anterior members, and not any of its bones were permeated by air-cells. This bird forms the most striking and characteristic type of the Fauna of New Zealand.

The organic remains of the most recent deposits of the North Island, which are most probably contemporary with the post-pliocene formations of Australia and Europe, are referable to an apparently extinct genus of Struthious birds, having the nearest affinities in the dense structure and medullary cavities of the bones to the Apteryx. The remains of this genus (*Dinornis*) appear to be very abundant, notwithstanding the stupendous stature of some of the species; since I communicated my notice of it to the Zoological Society in 1839, six extinct species have been well-established†, on the evidence of abundant remains collected by the Rev. Mr. Williams, Mr. Colenso‡, and Mr. Cotton, at Poverty Bay, Wanganui and Wairoa. It is reported that a species of *Dinornis* still exists in the South Island of New Zealand; and it is not improbable that some of the species may have been living when the aborigines first set foot on the North Island. But the bones which have reached me from the North Island, although retaining much of their animal matter, are more or less impregnated with ferruginous salts, and may have lain in an argillaceous soil for as long a period as some of the latest extinct Mammals of Australia, South America and Europe. At all events, so far as our knowledge of the living and the last-exterminated Fauna of the warm-blooded animals of New Zealand extends, it shows that the same close analogy existed between them, as it is the object of this Report to exemplify in the larger natural divisions of the dry land on the present surface of this planet.

I am far however from assuming that our present observations are sufficiently extensive to have established the law of the geographical distribution of the Mammalia of the pliocene and post-pliocene periods; to speak of the sum of such observations under the term 'law' may, perhaps, be deemed premature. But the generalizations enunciated in the present Report appear to be sufficiently extensive and unexceptionable to render them of importance in a scientific consideration of the present distribution of the highest organized and last-created class of animals; and to show that, with extinct as with existing Mammalia, particular forms were assigned to particular provinces, and, what is still more interesting and suggestive, that *the same forms were restricted to the same provinces at a former geological period as they are at the present day*.

I have purposely refrained from pursuing the comparison of recent and extinct Mammalia, in reference to their local distribution, to the eocene epoch: too little is known, or can reasonably be conjectured, as to the relative distribution of sea and land on the surface of the globe at that remote tertiary period, to elucidate the relations of geographical sites of continents to particular groups of animals.

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* Elements of Geology, 8vo, 1838, p. 366, and Principles of Geology, 1837, vol. i. p. 204.

† Transactions of the Zoological Society, vol. iii. pp. 32 and 235.

‡ An interesting account has been published by this gentleman in the Tasmanian Journal of Natural History, vol. ii. No. vii. 1843.

Report on the Working of Whewell *and* Osler's *Anemometers at Plymouth, for the years* 1841, 1842, 1843.

By W. Snow Harris, *Esq., F.R.S., &c.*

There is no department of meteorology in so unsatisfactory a state as that relating to the general course and velocity of the wind, especially in high latitudes; for although many talented persons have given their attention occasionally to this subject, and a variety of instruments for measuring the force and velocity of the wind have been suggested, yet no series of observations conducted upon any definite or correct view of the great periodical and other movements of the air, and embracing the question in all its generality, has, so far as I can learn, been ever fairly carried out, so that we yet require careful investigations by means of simultaneous observation, and with instruments well-adapted to the purpose, in order to appreciate with anything like accuracy the phænomena of winds and the laws of atmospheric circulation.

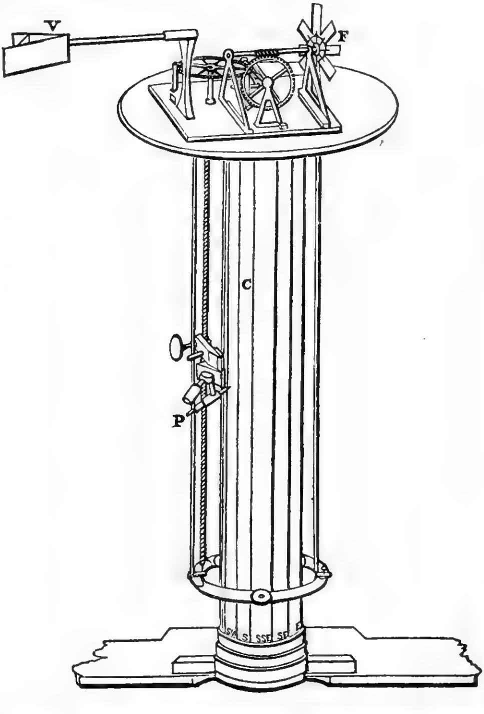
Meteorology, as a predictive science, is certainly very defective; almost every change in the state and condition of the air is generally considered quite an affair of chance, yet such is not really the case; the philosopher knows nothing of chance, and is well assured that every atmospheric variation is the result of unerring laws.

The laws of the periodical movements, and general circulation of the air about our globe, demand very special attention, as being intimately associated with future atmospheric changes. It is not improbable, from the great regularity of the winds in latitudes but little subject to capricious variations, that even in higher latitudes a similar regularity may upon the whole become apparent, in eliminating by a sufficient number of observations the forces which disturb the general course of the winds in these latitudes.

The great defect of the partial methods hitherto pursued in observing and recording the winds, has been a want of due attention to their force and velocity; the direction, together with the time which any particular wind blows, being the only elements usually considered. We have it is true one or two useful tables by Rous, Hutton and others, expressing the common designation of certain winds and the velocity due to certain pressures, but these do not appear to have been employed in obtaining any general meteorological deduction, such as the mean direction and rate of motion of the air in a particular place for any given period, and which it is most important to determine. To arrive at this, however, we require a correct register of the direction and velocity or some other element from which the velocity may be determined. Professor Whewell has well explained this in his valuable paper in the Cambridge Philosophical Transactions, vol. iv. Indeed it is quite evident, that more air may be transferred over a given place in one day by a wind blowing with great force in a certain direction, than would move over the same place in a week by the gentle breezes of a wind blowing in an opposite one, and hence any inquiry which does not embrace this essential principle in anemometry, cannot be productive of correct results. Kæmptz, with a view to the generalization of the winds of different latitudes, has, in the absence of all record of their velocity, supposed them all equal in force, and takes their duration as the measure of their value, considered as so many distinct forces.

It was with the intention of obtaining a more perfect investigation of this question, that the British Association confided to my care the anemometers designed by the Rev. Professor Whewell and Mr. Osler of Birmingham, both of which were so theoretically constructed as either to give at once the integral force of the wind, that is to say, the velocity conjointly with the time, or otherwise the elements from which this integral force may be determined; and it will be my endeavour in this report to show how far these instruments are calculated for such a purpose.

Whewell's Anemometer.—It does not seem requisite to enter here upon any lengthened description of this instrument, inasmuch as a very full account of it has already appeared in vol. ix. and x. of the Reports of the Association. It may however be desirable for the sake of perspicuity to revert briefly to its general character as shown in the annexed cut.



By means of a vane V a windmill fly F is constantly presented to the wind, and it revolves more or less rapidly according to the velocity of the current. An intermediate train of wheels, &c. operated on by the fly F, causes a pencil P to descend vertically over a fixed cylinder C, leaving a trace thereon of variable length, according as the wind is more or less strong. The direction is shown by vertical lines on the cylinder, corresponding in position to sixteen points of the compass, and upon some one of which the pencil P is brought to act by means of the vane V. Supposing the fly F to revolve in the simple proportion of the velocity of the wind, we obtain in the length of the trace or line described by the pencil, a space proportional to that which a particle of air would describe in a given direction in a given time, say one day, taking into the account the strength of the wind and the time for which it blows. Finally, by collecting these integral results and laying them off successively by the graphical method of delineation, we obtain as in Plate XXXIII. figs 1, 2, 3, what may be considered the path of the wind for a given period of time. The mean annual path thus obtained in any given place is called the type of the wind for that place. As an abstract philosophical principle nothing can be more perfect or better adapted to the end proposed to be attained, and although the mechanical arrangements which have been resorted to in order to carry it out effectually in practice may not be the best possible, yet I shall endeavour to show that we have by means of this instrument still arrived at extremely valuable examples of its general application.

In Plate XXXIII. figs. 1, 2, 3, will be found graphical delineations of the path of the wind at Plymouth for the years 1841, 1842, and 1843, as laid off from daily observations with this instrument: the scale is sufficiently large to indicate the successive changes which have occurred in these years.

On examining these annual types, we find, as in the former observations published in vol. vii. of the Reports of the Association, that the general course of the air is towards the land, and varies between N.E. and N.W. The current appears to be interrupted in its general course by certain disturbances or tourbillons which tie as it were so many knots in its path and which are almost periodical. Thus in the type of 1841, fig. 1, there are four of these disturbances, viz. about January, April, July, and November. The general course of this type is nearly N.N.E.

The type of 1842 presents also four marked disturbances, viz. about January, March, August, and October. The general course here is N.N.W.

The type of 1843 has again four tourbillons or knots, viz. January, April, July, and October. The course here is a little to the east of north.

These disturbances evidently approach a periodical form. Thus we have a complete disturbance about the commencement of each year, which is further shown in Plate XXXIII. fig. 4, in which are laid off the two months' observations of the year 1844. About the months of March and April we have a second disturbance; a third about the middle of summer, and a fourth about the period of autumn. These disturbances, although not perfectly coincident, still show so great an approximation, as to render their dependence on a similar cause highly probable; and since they are found about the periods of the vernal and autumnal equinoxes and of the solstices, it is not unreasonable to conclude that they result from the peculiar position of the sun at those periods.

The complicated path or type of the wind at the time of these disturbances is not unworthy of attention. In Plate XXXIV. fig. 5, will be found laid off, on a large scale, the disturbance observed in the autumn of 1842. In this example the wind is at the point *a p*, twice coincident in its general mean direction, and has been twice thrown out of it, and there is a general resemblance in the course it has taken on both these occasions; in both cases it has been traced southerly and westerly, as at *a* and *b*. The wind did not recover its general mean course in this case until after October.

These effects point out the necessity of observing the instrument for a long period of time, and not merely for the space of a month or two; for should the observations happen to be made at the time of these periodical disturbances, and the results laid off on a large scale, very indefinite views would arise relative to the general movement of the air.

This method, adopted by Professor Whewell, of figuring the path of the wind, although extremely ingenious and even indispensable where we wish to present to the eye the successive changes which have occurred, is still not the only form under which the observations may be discussed. There is yet another method of dealing with the register, which should be also noticed.

If we consider the different winds, when reduced to any given number of points of the compass, as so many forces whose directions are given, and take their relative intensities for the time during which each wind is recorded, then it is evident that we may proceed to deal with these forces in intensity and direction in the same way as we should deal with any other number of mechanical forces under similar circumstances, and hence obtain the resultant of these forces representing the different winds for any given time; and if we take the intensity in terms of velocity, we may arrive at the mean annual movement of the air both in velocity and direction, together with other periodical movements of no less importance to the present state of meteorology.

With this view I have laid down in the annexed tables the general results of this anemometer for certain great periods of time. In Tables I. II. III. will be found the respective quantities of wind to sixteen points of the compass for the successive months of the years 1841, 1842, and 1843, together with the total amount for each year.

In Table IV. will be found the mean quantity of each wind for the three years, as deduced from the sums of Tables I. II. III.

In Table V. are given the effective winds reduced to eight points of the compass, by subtracting the lesser amount of wind from the greater for opposite directions, so that by the prevalence of certain winds over others, eight points of the compass vanish.

In Table VI. will be found the mean results of the three years, also reduced to eight points of the compass in a similar way.

Table VII. contains the mean quantity of wind for each of the four seasons, as deduced from the mean results of Tables I. II. and III. March, April and May are here considered as months of spring; June, July and August summer months; September, October, November, months of Autumn; and December, January, February, winter months.

Table VIII. shows the reduction to eight points as before.

Table IX. comprises the two months' observations for the year 1844, at which time they were discontinued.

These Tables enable us to deduce, by the method just explained, the mean direction and velocity of the wind for certain periods of time, as shown by this instrument, and which is effected in Plates XXXV. and XXXVI.

In Plate XXXV. figs. 6, 7, 8, will be found the eight effective winds of the years 1841, 1842, and 1843, laid off for each year as a polygon of forces, and in fig. 9 the mean results of these years are laid off in a similar way.

In constructing these figures the winds have been taken in the order of following points of the compass, the forces being deduced from Table V. The effective winds in this order for the three years, together with the mean, are given in Table X.

It will be seen by these figures that comparative values of the wind in velocity and direction have been arrived at; and that an instrument, if sufficiently perfect in its mechanical details on this principle, would be of great importance to meteorology.

The result of 1841 (fig. 6) gives a mean direction N. 15° east, the relative magnitude of the resultant on the scale of measure being 4180.

The result of 1842 (fig. 7) gives a mean direction N. 12° west, the relative magnitude of the resultant being 3800.

The result of 1843 (fig. 8) has a mean direction N. 2° east, the magnitude of the resultant being 2810.

The mean result (fig. 8) has a mean direction N. 1° east, the magnitude of the resultant being 3500.

Although these different resultants represent the relative spaces which a particle of air would have passed over in each of these years in the given directions, if acted on by a single force equivalent to all the others, yet they do not give us any information of the actual velocity of the wind in these different years. Now it is most desirable, if possible, to discover this, since for the future progress of anemometry it is not only relative but absolute values we require.

The method by which I proposed to arrive at this has been already pointed out in the Reports of the Association for 1842, and although to a certain extent empirical is still not without claims to consideration, and it is moreover the only one apparently within our reach. This method consists in determining experimentally, the actual space passed over by the pencil in a given time corresponding to certain velocities of the wind, and finding from this how these spaces vary with the velocities.

To this effect I examined the best tables of the relative force and velocity of the wind laid down by Rous, Lind, Hutton and others, and by some further experiments enlarged and extended them. I found that observations with a gauge on Lind's principle were sufficiently accurate for my purpose, and accordingly noted the indications of this instrument simultaneously with the anemometer now under consideration.

In a former but rather limited series of experiments, the spaces passed over by the pencil came in several instances near the proportion of the square of velocity of the wind. In very strong and steady breezes, however, the spaces passed over by the pencil came nearer the simple ratio of the wind's velocity. When the obstacles arising from the friction and resistance of the machine bear a high proportion to the force which sets it in motion, then, as may be readily conceived, the space passed over by the pencil is less than it would be if no such retarding force existed. As the velocity of the wind increases the resistance is comparatively less, until it may be at last so small as not to interfere considerably with the revolutions of the fly; accordingly we find that in strong winds the ratio between the revolutions of the fly and the velocity of the wind give a constant quantity, the spaces described by the pencil being taken as proportionate to the revolutions of the fly.

If we consider attentively the nature of the mechanism in this machine, it will be seen that the friction is very considerable. We have for example (see figure in page 242) perpetual screws working in toothed wheels, so as to convert the rapid motion of the fly into a slow descending vertical motion, again carried out by a thread turning within a moveable nut. We have further the friction of a pencil attached to this nut, against a fixed cylinder so as to leave a trace on it. This instrument therefore involves the greatest amount of friction incidental to any mechanical machine. We may therefore conceive that with gentle winds and light breezes the motion of the fly would experience a greater amount of comparative retardation than with strong gales; hence in the construction of instruments on this principle we should employ a fly of considerable power as compared with the work the machine has to perform.

In Table XI. will be found the mean results of a series of experiments on the indications of this instrument, as compared with the velocity of the wind deduced by Lind's gauge.

We may observe in this table, that when the breeze is strong the velocity of the wind (taken in feet per second) divided by the space passed over by the pencil gives in several consecutive experiments a constant quantity, or nearly so. This is seen in observations 4, 5, 6, and 6, 7, 8, and 9, 10, 11, 12. In these instances therefore, as compared with each other, the velocity of the fly is nearly in proportion to the velocity of the wind. This however is not the case in comparing more distant observations. Thus in observations 1 and 7, the velocity of the wind is as 1 : 2, whilst the space passed over by the pencil is as 1 : 3. In the first and tenth series of observations it approaches the square of the velocity of the wind. In fact it is evident by column *f*, that the ratio of the velocity of the wind to the velocity of the fly is continually decreasing by a variable quantity. In looking over some of Coulomb's experiments on the working of windmills, we find a similar result. Thus when velocity of wind was 7 feet per second, the sails made 3 revolutions per minute; and these quantities increased in the following proportions:—

Feet per second.		Revolutions of sails.
12·5	gave	7·5
20	......	13
28	......	22

Here the ratios are 2·3, 1·7, 1·6, 1·2. Hence the ratio of the velocity of the wind to the revolutions of the sails is continually decreasing. But there are other forces interfering with the ratios of the velocity of the wind to the velocity of the fly which render deductions from this machine somewhat difficult, such as the resistance of the air to the motion of the fly and such like, all of which require considerable attention in the construction of anemometers on this principle.

Taking however the observations we have recorded with this machine as fair examples of the nature and operation of its working, and of the kind of information it would put us in possession of, were it so constructed as to meet all these questions, they are upon the whole very valuable, and we shall see how they may be further applied and received in the way of approximation to a correct result.

If we suppose in Table XI. that the ratios had continued to increase in column *f* as the spaces described by the pencil diminished, and in the proportion of the preceding numbers, we should have for a descent of the pencil at the rate of one division of the scale of measure per hour, a corresponding velocity of wind equal to about ten feet and a half per second; and for a rate of ·5 of a division of the scale of measure per hour, a corresponding velocity of wind equal to about seven feet per second. Taking then 10·6 feet per second as the velocity of the wind corresponding to the descent of the pencil at the rate of one division of the scale per hour, which was about the proportion found by a mean of observations, we may take the velocity of the wind corresponding to half a division of the scale per hour as 7 feet per second. If then we apply this result to the resultants in Plate XXXV. we have in dividing these resultants by 8760, the total number of hours in the year, the mean rate of the pencil per hour expressed in terms of the scale of measure, and hence the general results will be as follows:—

Years.	1841.	1842.	1843.	Mean by this Table.	Mean by fig. 6. pl. XXXV.
Mean direction of wind...............	N. 15° E.	N. 12° W.	N. 2° E.	N. 1½° E.	N. 1° E.
Integral result	4210	3800	2810	3607	3500
Rate in divisions of scale per hour..	0·48	0·433	0·32	0·412	0·4
Feet per second	6·7	6·	4·48	5·76	5·6
Miles per hour	4·5	4·	3·	3·9	3·8

The great annual movement of the air therefore would by observations with this instrument be N. 1° east, at the mean rate of 3·9 miles per hour.

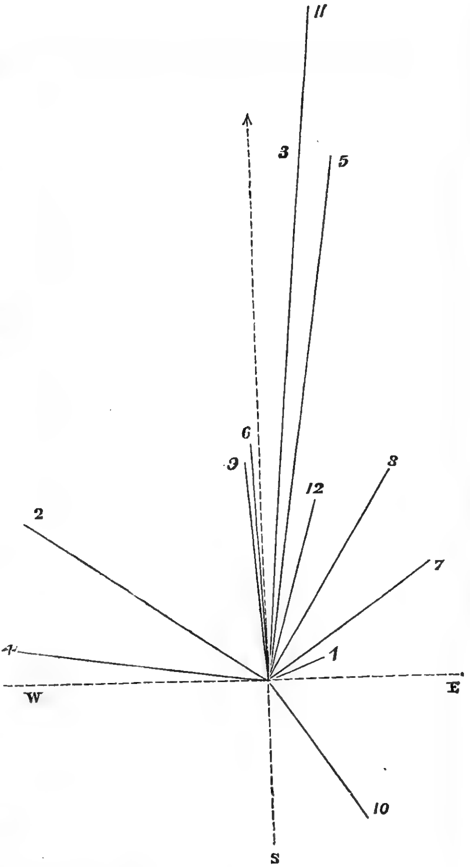
In Table XII. will be found the effective amounts of wind for each month, as deduced from the mean of the three years by Tables I. II. III., and from these we may determine the mean monthly direction and velocity of the current, at least so far as these observations are to be relied on. The winds in quantity and direction in this Table, when laid off as already shown in Plate XXXV., will be found to give the following results:—

Months.	Direction of Resultant.	Direction of Wind as commonly expressed.	Integral Results, or Total Wind.	Mean Rate per hour in Divisions of Scale.	Velocity of Wind.	
					Feet per second.	Miles per hour.
January ...	N. 67° 30′ E.	W.S.W.	75	0·1	1·4	0·95
February...	N. 56° W.	S.E. by E.	300	0·44	6·16	4·2
March......	N. 4° 30′ E.	S. ½ W.	610	0·8	11·2	7·6
April	N. 81° 30′ W.	E. ¾ S.	302	0·41	5·7	3·84
May	N. 7° 30′ E.	S. ¾ W.	475	0·6	8·4	5·75
June	N. 3° W.	S. ¼ E.	270	0·37	5·2	3·5
July	N. 56° E.	S.W. by W.	140	0·19	2·6	1·75
August ...	N. 29° 30′ E.	S.S.W. ¾ W.	298	0·4	5·6	3·8
September.	N. 4° W.	S. ½ E.	250	0·34	4·76	3·25
October ...	S. 30° 45′ E.	N.W. by N.	100	0·13	1·82	1·2
November..	N. 4° 20′ E.	S. ½ W.	780	1·00	10·6	7·0
December..	N. 17° E.	S. by W. ½ W.	440	0·6	8·4	5·75

The relative directions and magnitudes of these resultants for each month are shown in the annexed cut, the months being numbered 1, 2, 3, 4, &c.

The greatest mean monthly velocity in the resulting directions is by these results in March and November; and the least in January and October; the mean direction of the current in March and November being nearly the same. Southerly winds prevail in March, and northerly in October, and easterly winds in April, that is, upon the mean of these three years: for the remaining months the wind generally blows upon the land from some point between W.S.W. and E.S.E.

The effective winds in the order of following points for each of the seasons of spring, summer, autumn, and winter, are given in Table XIII., as deduced from the mean results in Tables VII. and VIII. These are laid off in figs. 10, 11, 12, 13, Plate XXXVI., and give the following results :—



Seasons.		Spring.	Summer.	Autumn.	Winter.
Direction of resultant		N. 10° W.	N. 20° E.	N. 6° E.	N. 6° W.
Wind as commonly expressed		S. by E. nearly	S.S.W. nearly	S. ½ W. nearly	S. ½ E. nearly
Integral amount........................		1143	645	1154	634
Rate in divisions of scale per hour..		0·5	0·294	0·527	0·289
Velocity	Feet per second	7·0	4·1	7·38	4·0
	Miles per hour	4·75	2·8	5·00	2·7

By these results it appears that the greatest amount of wind is in the spring and autumn, the least in summer and winter. By the types in Plate XXXIII. the current advances more steadily and rapidly in its course in the spring and autumn than in the summer and winter. It must be remembered, however, that in all these deductions we are speaking of the integral or total effects; the mean daily velocity of the wind, taken without regard to direction, may be of itself very considerable, and yet by the neutralization of opposite forces the great mass of the air may have made but comparatively little progress in a given direction.

By generalizing the mean results in Table IV. we obtain the comparative amount of wind from opposite points of the compass. Thus calling the winds between N.N.E. and N.N.W. exclusive, north winds; those between S.S.E. and S.S.W. exclusive, south winds; and so on, and then taking the mean integral amount, we have for eight opposite points thus reduced the following comparative numbers:—

North	386	West	295	South-east	150	North-east	417
South	1793	East	308	North-west	312	South-west	929,

by which it appears that the mean amount of north winds including 45 degrees, is less than that of south winds, in the ratio of 1 : 4 at least.

The mean amount of west wind is less than that of east, in the ratio of 1 : 1·7 nearly.

The mean amount of south-east is less than that of north-west, in the ratio of 1 : 2 nearly.

The mean amount of north-east is less than mean amount of south-west also, in the ratio of 1 : 2 nearly.

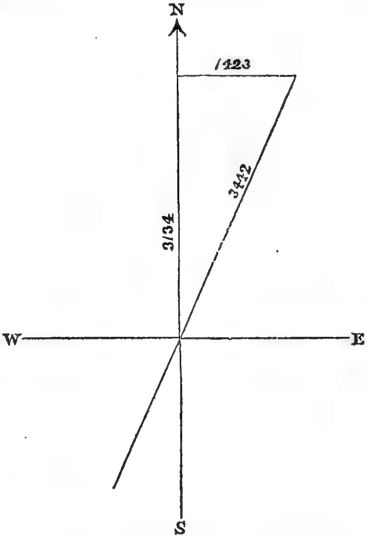
It must be borne in mind, that in generalizing the results of this instrument we are not considering the *prevalence* or *frequency* of any particular wind in a given place, but its particular or integral effect, that is to say, the comparative distance over which a particle of air would pass during the time a certain wind blows; and this may with a strong east wind of only one day, far exceed in effect the breezes of a gentle west wind of a week. If we take in Table IV. the total mean amount of wind in the north semicircle, and also that in the south semicircle, from east to west *exclusive*, calling those on the north side, north winds, and those on the south, south winds, we obtain the following results:—

North 2672, south 5806, being in the ratio of 1 : 2.

Treating the east and west semicircles in a similar way from north to south exclusive, we have, east 2697, west 4120, being a ratio of 1 : 1·5 nearly.

Reducing these numbers to two effective forces by subtracting the north from south and east from west, we have for a final result, south 3134, west 1423, that is to say, two rectangular forces, whose intensity and directions are given and whose resultant may therefore be easily found.

The direction of this resultant will be N.N.E., the wind being S.S.W., as in the annexed figure, and its magnitude $=\sqrt{(3134)^2+(1423)^2}=3442$ nearly; this divided by 8760, the number of hours in the year, gives a rate of ·4 per hour in divisions of the scale of measure for the descent of pencil, which by previous deductions from Table XI. would in taking $\frac{1}{2}$ a division of the scale of measure = to 7 feet per second, give a velocity of 5·6 feet per second, or 3·8 miles per hour, a similar result to that already arrived at, with the exception of a little deviation in the direction.

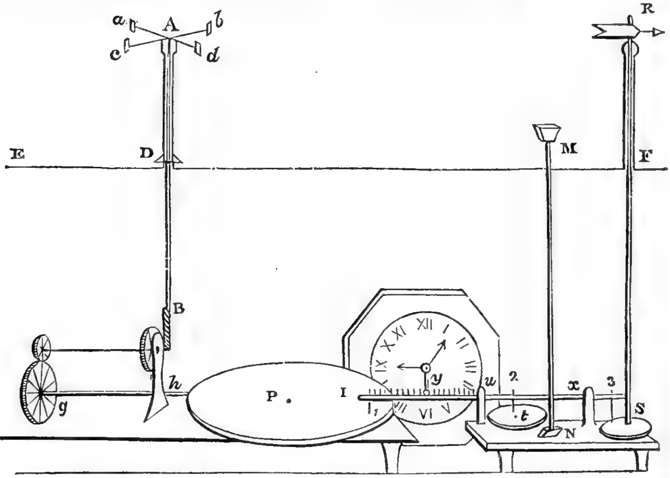


Such are the principal results of the working of this instrument during the years 1841, 1842, 1843; and could we feel assured that it had worked with perfect accuracy, we should doubtless have arrived at very important results. This is however unfortunately not the case, and therefore these results can only be taken in the way of rough approximations.

The integral effects, in fact, have been deduced on the supposition that the revolutions of the fly are proportional to the velocity of the wind, whereas we see by Table XI. that they only approach this ratio in certain cases, and differ from it considerably in others. The relative effects also of the wind on the fly and vane are unfavourable to a very correct direction, in consequence of a tendency in the top to be thrown occasionally a little oblique to the course of the current, so that it is possible that the direction is not always to be depended on. Professor Airy, in his experience of this anemometer at Greenwich, thinks it cannot be depended on for direction; he says it turns very heavily in azimuth, an objection however to which the instrument at Plymouth is not liable since it was last set up.

With all these difficulties, however, I am encouraged to hope that the examples just given of its operation for three years, together with the deductions we have made by a careful analysis of the register, may not be altogether without claims to attention; beside that they hold out inducements to ingenious mechanics and meteorologists to improve its construction, and extend the principle to more perfect machines, from which certainly the most important consequences would result. To render an anemometer of this kind perfect, experience has taught us, that it should be a permanently fixed machine, and set up in a commodious and convenient form; it should consist of several separate parts, all of them independent of each other, viz. a vane for registering direction only, unembarrassed by any other mechanical detail; the most simple and effective form of vane is that of a flying-fish with extended fins, balanced at about one-third from the head. Secondly, a powerful fly or horizontal windmill, so contrived as to revolve in one direction only and register the integral of the wind. The power of this fly should be in such a ratio to the friction of the machine as will admit of the latter being thrown out of the calculation, so that it could always revolve with a rapidity proportional to the winds' velocity, and with which it should be *absolutely* compared. Thirdly, there should be some means of registering the actual pressure of the current on a given area, either by a pressure-plate or a column of fluid on Lind's principle; the former is perhaps to be preferred, as admitting of a greater degree of precision. There should also be a rain-gauge connected with the instrument, and the whole should be regulated by a good time-keeper, so as to give a constant register of these elements for known periods of time.

I am not exactly prepared to say at present how the mechanical detail of such an anemometer could be best carried out, so as to get the machine within a small and convenient compass; but from some considerations which I have been led to, I do not think it would be difficult to accomplish. In support of this opinion, I venture to submit to the Association the following most ingenious arrangement, kindly communicated to me by the Rev. W. Foster of Sturbington, near Portsmouth in Hampshire, and which completely embraces some of these views. The general nature of this machine will be easily apprehended by reference to the annexed cut.



A is a cross horizontal fly of three feet in diameter, having four vanes, *a*, *b*, *c*, *d*; these vanes are six inches square, and are so contrived as to cause the fly to revolve in one direction only. By the revolution of this fly motion is communicated to an endless screw B at the termination of the vertical shaft A B attached to the fly, and passing through the roof of the house at D the fly is supported on the hollow tube A D. By means of the endless screw at B a train of mechanism is put in motion, which motion is finally communicated to the axis *g h*, and by this through another endless screw, not shown in the figure, to the disc P, so that this disc, which is twenty-two inches in diameter, is caused to revolve slowly in a horizontal plane, hence the motion of P registers the revolutions of the fly A, the revolutions of which may be in any convenient proportion to those of the disc 1 : 10·000 or 1 : 20·000.

R is a vane, and R S a vane rod, working also through the roof at F, by which a similar horizontal disc S is turned about a centre; this disc is nine inches in diameter. M is a rain receiver, and M N a pipe by which the rain descends into a gauge N; this gauge consists of two compartments in the usual form of balance-gauges, so that when one compartment is full the balance oversets and allows the other compartment to go on filling; a reciprocating motion is thus produced, by which an axis is caused to work in a toothed wheel (not seen in the figure) under the disc *t*, causing it to revolve through a space proportionate to the quantity of rain delivered at each tip of the gauge N.

I *u x* is a rod set on friction-rollers at *u* and *x*; it is furnished with a rack, I *u*, to receive the single tooth of a horizontal rod, *y*, projecting horizontally from the centre of the clock *y*. There are twenty-four teeth in the rack, and thus the rod is moved hourly one division; by this motion three pencils, numbered in the figure 1, 2, 3, are hourly moved upon the respective discs I *t s*, so that traces are obtained of the direction and velocity of the wind and of the rain for every hour as the discs move under the pencils.

This instrument is reported to have stood severe gales without having sustained any damage, and to have answered very perfectly. The following are some results of its operation from November 1843 to November 1844.

TABLE A.

Showing Hourly Velocity of Wind by Foster's Anemometer, from November 1843 to November 1844.

Hours A.M.	Velocity in miles.	Hours P.M.	Velocity in miles.
1	2434	1	4161
2	2364	2	3992
3	2318	3	3806
4	2062	4	3698
5	2193	5	3263
6	2437	6	2978
7	2687	7	2625
8	2894	8	2426
9	3374	9	2317
10	3608	10	2306
11	3881	11	2428
12	4079	12	2433

TABLE B.

Showing the Total and Mean Hourly Velocity of each Wind in miles, by Foster's Anemometer.

Points of Compass.	Total Velocity in miles per hour.	Number of hours of each wind.	Mean Hourly Velocity in miles.	Points of Compass.	Total Velocity in miles per hour.	Number of hours of each wind.	Mean Hourly Velocity in miles.
N.	432	42	10·3	S.	1811	136	13·3
N.N.E.	3828	354	10·6	S.S.W.	2787	149	18·7
N.E.	4468	317	14·2	S.W.	5773	265	21·8
E.N.E.	2491	147	17·	W.S.W.	10227	609	17·0
E.	948	75	12·6	W.	6836	383	17·0
E.S.E.	854	68	12·5	W.N.W.	16301	877	18·5
S.E.	699	81	8·6	N.W.	6695	412	16·2
S.S.E.	1125	77	14·6	N.N.W.	3011	298	10·1

Mr. Foster has estimated the general direction and magnitude of the resultant in the following way :—One-half the velocities of north-west and north-east winds are taken and added to the velocities of the intermediate points, calling the total north.

In a similar way one-half the velocities of south-west and south-east winds are taken and added to the velocities of the intermediate points, calling the whole south, and so on, according to the following formulæ:—

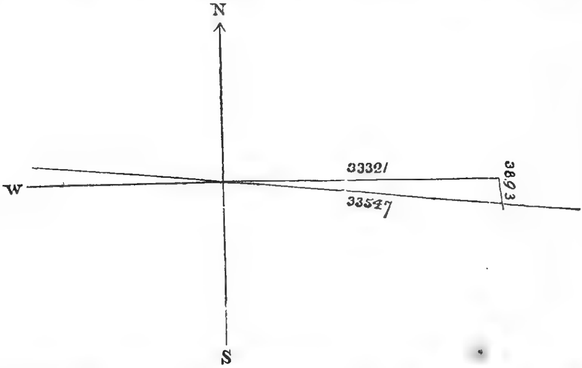
$$\frac{\text{N.W.}}{2}+\text{N.N.W.}+\text{N.}+\text{N.N.E.}+\frac{\text{N.E.}}{2}=\text{N.}$$

$$\frac{\text{S.W.}}{2}+\text{S.S.W.}+\text{S.}+\text{S.S.E.}+\frac{\text{S.E.}}{2}=\text{S.}$$

$$\frac{\text{N.E.}}{2}+\text{E.N.E.}+\text{E.}+\text{E.S.E.}+\frac{\text{S.E.}}{2}=\text{E.}$$

$$\frac{\text{N.W.}}{2}+\text{W.N.W.}+\text{W.}+\text{W.S.W.}+\frac{\text{S.W.}}{2}=\text{W.}$$

Substituting the arithmetical quantities in Table A in these formulæ, we have N. = 12852, S. = 8959, E. = 6276, W. = 39598. Subtracting S. from N. and E. from W., we have the two rectangular forces, N = 3893, and W. = 33321, the resultant and direction of which will be as in the annexed figure. Magnitude of resultant = $\sqrt{33321^2+3893^2} = 33547$. Dividing by 8760, the total number of hours in the years, gives about 3·8 miles per hour. The direction of the wind therefore in the locality of this instrument, from November 1843 to November 1844, would be about W.N.W. to E.S.E. with a velocity of 3·8 miles per hour, being a velocity the same as that obtained by Professor Whewell's instrument.



The Right Honourable the Earl of Burlington, one of the late Presidents of the British Association, has been so good as to place in my hands some manuscripts found amongst the papers of the late Mr. Cavendish, and containing no doubt the results of valuable experiments on revolving vanes, which would be likely to throw some further light on the working of such instruments as this; but from the absence of all information relative to these experiments, it is impossible to come to any satisfactory conclusions relative to them. Mr. Cavendish, who left few inquiries in experimental science untouched by his powerful hand, had evidently considered the subject of revolving vanes as a means of determining the velocity of the wind. His experiments were made on machines of considerable magnitude, the arms on which the vanes were fixed being nearly ten feet long, the total diameter of the fly therefore was twenty feet; the motion of this fly appears to have been estimated by the motion communicated to some other secondary machinery, termed the gauge, as we find on Mr. Cavendish's manuscript the following remarks:—"Rad. circle which it revolves in = 10 feet and circumf. = 62·83 feet, and by mean gauge makes 3·73 rev. for 1 rev. arm, and therefore makes 1 rev. for 16·85 feet, or $\frac{1}{313}$ of a mile, therefore, as in former trials, it seemed to make 360 rev. per mile." He also says, "Diameter of vanes is 14·2 inches, therefore vanes make one revolution whilst wind moves over $4\frac{1}{2}$ times the circumference, and consequently if wind is $4\frac{1}{2}$ slower at leading edge of vanes than at the other, they should stand still."

This instrument worked very freely with light breezes, and when the wind did not exceed 1 mile per hour, or 1·43 feet in a second, the fly appears to have made "2·62 rev. in $\frac{1}{2}$ min." Such a wind as this, according to Rous, is scarcely perceptible, and would not exert more than ·005 lb. pressure on a square foot; it is not measurable by any anemometer at present employed in meteorology. One revolution of this instrument per second = 9·955 miles per hour.

I have thought it desirable to notice these remarks in Mr. Cavendish's papers with a view of showing how possible it is to measure the velocity of very slow currents, and furnish some hints at least relative to the method which this profound and accomplished scholar and philosopher resorted to for the purpose.

Osler's Anemometer.—A full description of this instrument has been given by the inventor in a quarto pamphlet printed at Birmingham about five years since; no particular notice or figured description of it however has yet appeared in the Reports of the British Association, notwithstanding that several sums of money and much labour has been devoted to it. I have thought it therefore desirable to preface what I have at present to state relative to this anemometer, with a very brief notice and drawing of its principal parts, in order the more effectually to carry out the object of this Report, viz. a full account of the results of the experiments undertaken by the Physical Section of the Association for the purpose of advancing that department of meteorology relating to the phænomena of wind.

Osler's anemometer traces the direction and pressure of the wind on a given area, together with the amount of rain, on a longitudinal register divided into twenty-four portions, corresponding to the twenty-four hours of the day, as shown by fig. 1, Plate XXXVII. The central portion of this paper is devoted to the register of the direction, and has a series of longitudinal lines on it corresponding to the cardinal points. The lower portion, *b d*, is devoted to the register of pressure, and is graduated also by a series of longitudinal lines corresponding to lbs. pressure on the square foot. The upper portion, *a c*, is devoted to the register of rain, and is graduated in a similar way by a series of lines corresponding to given quantities. Finally, the whole length is divided by verticals or lines perpendicular to the former, as 1, 2, 3, 4, &c., corresponding to the twenty-four hours of the day. This register-paper being placed on a board M, fig. 2, and accurately set every day, is carried along by means of a clock, C, under three pencils, 1′, 2′, 3′, which may be considered as the fingers or indexes of the machine. The board M moves on friction rollers, and is hence easily drawn along as the clock, and consequently the time, advances.

The pencil 1′ is the index of direction; this pencil is operated on by a vane V, turning a vertical hollow shaft, W *p*. There is a pinion at *p* which, as the vane turns in the direction of the wind, acts on the rack-work of a transverse bar *e f*, and so causes it to move either to one side or the other. Now the pencil 1′ is attached to this bar, and hence is caused to leave a trace on one of the longitudinal lines of the register corresponding to the cardinal points, or some line parallel to those corresponding to intermediate points, such as N.N.W., N.W., &c.

The force of the wind is recorded by the action of a pressure-plate T, which by the vane V is presented to the direction of the current; this plate is sustained by two bars moving on friction rollers, and working through the hollow vane staff, as shown in the figure, the pressure of the wind on this plate is by these bars communicated to a spring inclosed in a tube *t*, the whole of which is sheltered by an outer case; as the spring becomes compressed it pulls on a wire-line not seen in the figure, which line, by means of small pullies, is led through the hollow vane staff, and finally brought to pull upon the spring lever *v*, and thus draw the pencil 2′ towards the rod: the height to which the pencil becomes raised on the graduated scale *b d*, fig. 1, represents the pressure of the wind in lbs. on an area of one square foot. The kind of trace left on the register is indicated in fig. 1.

The amount of rain is recorded in a somewhat similar way by the pencil 3′ attached to the spring lever *v*′. The rain, when it descends into the receiver R, is conducted into one of the compartments of a gauge *g*, balanced on an axis and sustained by a second balance, *g n*; as the water collects, this second balance, *g n*, begins to move and so raises the bob *h*. Now the spring lever *v*′ carrying the pencil 3′ is acted on by this bob, and hence the pencil is pushed forward upon the graduated scale *a c*, fig. 1, according to the quantity of water collected in the gauge; when the quantity becomes equal to $\frac{1}{4}$ of an inch in rain, or to a certain number of cubic inches on a foot square, then the little gauge *g* oversets, the water is discharged, and an opposite compartment of the gauge is brought under the pipe at *g*; the pencil of course now returns to its first position, and begins again to rise on the scale as the rain collects; a trace of this is shown in fig. 1; and it may be easily imagined that the more rapid the fall of rain the sharper will be the angles caused by the trace of the pencil; on the contrary, if the fall of rain be gradual and slow, the elevating or diagonal lines will be drawn out into a considerable length, as shown in the figure.

It is therefore evident that as the register M, fig. 1, becomes constantly and hourly drawn along under the three pencils 1′, 2′, 3′, a continued record or trace of the direction and pressure of the wind, together with the amount of rain, is left on the paper, an illustration of which is given in fig. 1.

The table on which the register-frame is supported is five feet long and about three feet six inches wide, with a strip cut out of the centre fifteen inches wide to admit the board M, and allow of its being gradually drawn along under the pencils.

The register-papers are about twenty-two inches long and a foot wide, and are placed daily on the board M.

Such are the principal features of the instrument which has been set up by the British Association at Plymouth, and also in Scotland and Ireland, for recording observations on the winds. I have not thought it requisite to enter upon any lengthened explanation of the several mechanical adaptations, or to complicate the figured description of it by lines representative of all the subordinate parts, as this would have only embarrassed the general account of it without any adequate return.

The use of this anemometer, such as just described, has been much impeded by the following circumstances:—First, the action of the pressure-plate is liable to frequent derangement from the violence of the wind, by which the wire-line communicating motion to the pencil below is broken; it is likewise from other defects in construction frequently uncertain, so that the register of the force is deficient; the tendency of the vane also to oscillate and change the position of the plate is another source of error, and there is also from this cause a considerable oscillation in the traces of direction. In violent storms, the vane often whirls round altogether and throws the pinion out of the range of the rack-work of the bar *e f*, and unless considerable attention be given in replacing it the direction is in error. From these and other contingencies, the registers which have come into my hands are far from perfect; nevertheless I have thought it desirable to go patiently over them with a view of obtaining such general deductions as the number of the clearly recorded observations are competent to furnish.

As this machine does not register integral results, but merely the pressure of the wind on a given area, it is requisite to find the mean velocities due to the several mean pressures, and multiply these into the time during which each wind blew.

The recorded observations being entered under prepared forms containing the directions of the wind to sixteen points of the compass for every twenty-four hours, together with the corresponding pressures at each hour; a mean force was obtained from several heights of the pencil on each side of the hour-line, not exceeding half an hour on either side, and the mean force thus determined was taken as the mean force of that hour. From these forces the mean pressure and total number of hours which each of the several winds blew were deduced. In order to turn these mean pressures into corresponding velocities, extensive tables of pressure and velocity were calculated from the labours of Rous, Smeaton, Hutton and others, as well as by reference to experiment, and from these the velocity of the wind in feet per second, or miles per hour, to any given pressure, could be readily found.

The registers however of Osler's anemometer which have come into my hands, inclusive of some lately received, are all very defective in continuous and perfect observation, and are beside occasionally interrupted by the damage done to the machinery of the pressure-plate during very violent gales. It became requisite therefore to resort to some approximate method of discussing such observations as the registers contain, so as to make them available for scientific deduction. The general method pursued in this case is as follows.

First. The forces clearly marked for the different directions of the wind were taken out and tabulated for a given period, together with the number of corresponding observations. From the numbers thus deduced, a mean pressure was deduced for each direction in dividing the sums of the recorded pressures by the number of observations.

Secondly. The mean pressures thus obtained were taken as an approximative value of the mean force of each wind, supposing the record had been complete in all its detail.

Thirdly. The total number of hours of each wind, in respect of direction only, were taken out and tabulated; the direction being pretty generally recorded when the pressure-plate was not acted on.

Lastly. The velocities in miles per hour due to the mean pressures were multiplied into the total number of hours of each wind, and the product taken as the integral effect, or the distance in miles a particle of air would have passed over in either of the given directions to sixteen points of the compass.

From these integrals the mean direction and velocity of the wind were deduced as before by geometrical construction.

In Table XIV. will be found the results of the registers of Osler's anemometer at Devonport for the years 1841 and 1842, as thus deduced, and from the last line of which we obtain the following effective forces in velocity and direction for these years.

Years.	S.S.E.	S.	S.S.W.	S.W.	W.S.W.	W.	W.N.W.	N.W.	N.N.W.
1841.	...	8981	5665	13333	5246	5063	6096	19417	1267
1842.	4123	10171	3148	9104	3708	1172	8644	16912	
Mean ...	1428	9576	4407	11218	4477	3118	7370	18164	

N.B. The mean of S.S.E. is the mean difference of S.S.E. and N.N.W.

These values being laid off geometrically as a system of mechanical forces, and as shown in figs. 13 and 14, Plate XXXVIII., we arrive at the following deductions, showing the general results of Osler's anemometer at Devonport.

Years.	Direction of Wind.	Integral in Miles.	Miles per hour.
1841.	E. 11° N.	42100	4·8
1842.	E. 17° N.	32000	3·65
Mean ...	E. 14° N.	37000	4·22

The direction of the current, as thus obtained, is, it must be admitted, rather different from that given by the observations with Professor Whewell's instrument, yet the mean velocity is not far different. This disagreement in respect of direction, although to a certain extent unsatisfactory, is perhaps not more than we might expect would happen in the present imperfect state of such instruments. It must, I think, be admitted that the direction given by Whewell's anemometer is too far north; and this error would probably arise from the circumstance that the machine does not do really what it professes to do, viz. trace a line always proportional to the space passed over by a particle of air in a given time. The revolutions of the fly, in fact, are not always proportional to the velocity of the wind, except in very strong breezes, as we have already shown in Table XI.; hence the weak westerly and northerly winds, so very prevalent in this place, and of which the vane of Osler's instrument has left traces, have not produced their full effect on Mr. Whewell's instrument, especially as compared with the generally strong southerly and easterly winds, which keep the fly in rapid motion; hence an undue prevalence in the records of these winds. On the other hand, the mean force of the north and west currents, so frequent in the records of Osler's anemometer, has probably been taken too high, it having been determined without reference to the frequency of the light winds which prevail from these quarters; and this, together with the failure of the instruments in registering all the strong southerly gales, has thrown the direction too far south. The mean direction of the wind at Devonport, as determined by the spaces which a particle of air would have passed over at the end of one year in each of the given directions, will probably be found eventually from south-west to north-east; at all events the limits of their direction is between north and east.

The Astronomer Royal, with his usual kind consideration for those engaged in scientific pursuits, has been so good as to place in my hands the very interesting volumes of the Greenwich Meteorological Observations for the years 1841 and 1842, by which I have been enabled to institute a comparison of the Plymouth with the Greenwich observations.

By the results given in pages 47 and 53 of the vol. for 1841, and in pages 78 and 85 for 1842, we are enabled to treat the results of Osler's instrument at Greenwich in a way similar to that just shown for Plymouth. Deducing the mean forces for the recorded observations, and the total hours of each wind from the two-hourly observations, we have similar elements to those before obtained; these are given in Table XV. From these we deduce the eight effective forces in velocity and direction, for each of the years 1841 and 1842, as follows.

Greenwich Observations.

Years.	S.	S.S.W.	S.W.	W.S.W.	W.	W.N.W.	N.W.	N.N.W.
1841.	2043	13080	12521	11170	12100	3312	3564	916
1842.	359	5491	13458	13663	4952	2309	1181	1843
Mean ...	1201	9286	12989	12417	8526	2810	2372	1379

These values, when laid off as before, figs. 15 and 16, Plate XXXVIII., give the following results.

Results of Osler's Anemometer at Greenwich.

Years.	Direction of Wind.	Integral in Miles.	Rate in Miles per hour.
1841.	E. 28° 30′ N.	47900	5·4
1842.	E. 27° N.	36750	4·2
Mean ...	E. 27° 36′ N.	42200	4·8

There is evidently a general agreement in the results of the Devonport and Greenwich observations, the mean direction of the wind being nearly the same, and the rate of motion of the air not very different; for it is to be considered that the Greenwich observations for 1841 only include a period of eleven months, whilst the approximative mean force has been deduced from a register of pressures not under a quarter of a pound; still the results are so far satisfactory as tending to show the same general course of the air in the annual movement in these latitudes, and which is evidently between the north and east, and at a mean rate of from four to five miles per hour, being about the same rate of motion as that deduced by the anemometers at Plymouth for the same years, a coincidence not unworthy of remark. There is likewise a very general agreement in the characters of the diagrams of the winds for these years, Plate XXXVIII. In both instances the year 1842 presents a less result than 1841, and the figures representing these winds at Devonport and Greenwich have a very similar relation. I cannot therefore but believe, that with perfect instruments of this kind, most valuable information would be obtained in this department of meteorology.

The registers of Osler's anemometer are still under investigation, and will be further reported on. I am enabled however to give in this report the relative velocity and amount of wind to eight points of the compass, in connexion with the atmospheric temperature and pressure and amount of rain for the two years just given, and which appears to be as in the following Table.

	Points of Direction.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.
a	Mean pressure...............	1·65	1·68	2·37	2·02	2·77	3·09	2·06	3·3
b	Velocity in miles per hour	18·3	18·47	21·7	20·28	23·75	25	20·46	25·9
c	Total hours	727	501	707	995	1112	1040	1004	1641
d	Integral effect...............	13304	9253	15342	20178	26410	26000	20541	42501
e	Barometer to 32°	29·875	29·880	29·816	29·798	29·642	29·717	29·751	29·891
f	Temperature	47·92	46·97	50·66	51·68	54·39	52·68	51·5	51
g	Rain in inches...............	1·303	0·294	1·404	4·647	7·987	6·218	2·950	1·544

In Plate XXXIX. these numbers are arranged upon the circumference of eight concentric circles, divided into eight points of the compass, so as to exhibit the routine of these elements under a circular form and in the order of the letters denoting them. Now by reference to this scheme, it may be perceived, that the integral amount of wind increases from a minimum at north-east, in passing round the circle by the south, to a maximum at north-west, after which it again decreases. The mean pressure in pounds on the square foot, and the mean velocity in miles per hour, do not vary for each direction more than might have been anticipated, the limits of the mean pressure being from ·5 of a pound to 2·5 pounds, and the velocity from 18 to 26 miles per hour.

The temperature of the air with these different directions of wind decreases from a maximum at south to a minimum at north-east in going round the circle by the west, after which it again increases.

The atmospheric pressure, on the contrary, proceeds in an opposite order. It increases from a minimum at south to a maximum at north-east in passing round the circle in the same direction, after which it again decreases. Thus when the temperature is greatest the barometric pressure is least.

The amount of rain increases from a minimum at north-east, in passing round the circle by east, to a maximum at south, after which it again decreases, being a course similar to that of the temperature.

Such are some of the results of the discussion of the observations made at Plymouth and Devonport with Whewell's and Osler's anemometers, and although we cannot consider them perfect, yet they are still most useful approximations, and fully show, that whatever may be the imperfections of these instruments, they comprise the elements of a valuable method of investigating the phænomena of winds by experimental means; and there can be, I think, but little doubt, that if a very perfect instrument involving these elements, were observed for a long series of years, most important information relative to the great periodical and other movements of the air would necessarily result.

It is not without much satisfaction I have to state that Mr. Osler has lately so much improved his anemometer that all the great imperfections are quite remedied, so that we now really possess a machine calculated to furnish a constant register of the direction and pressure of the wind. One of these instruments is now at work on that splendid building, the Royal Exchange, in London. The vane is no longer subject to the violent and irregular oscillating motion so common to vanes of the ordinary kind. In this new arrangement the pressure-plate is kept to its work by means of a small windmill-fly acting on a cog-wheel, similar to that on which common windmills are turned to the wind. The pressure-plate is of increased dimensions delicately hung on radius rods, and brought to act on a series of spiral springs, by which the least and greatest forces are registered, and that without any disturbing oscillation. These, with sundry other improvements in the mechanism and the method of registering the results, have certainly rendered the use of this instrument most important to meteorology.

TABLE I.

Showing the Amount of Wind for the year 1841.

Months.	N.	N.N.E.	N.E.	E.N.E.	E.	E.S.E.	S.E.	S.S.E.	S.	S.S.W.	S.W.	W.S.W.	W.	W.N.W.	N.W.	N.N.W.
January	292·0	24·0	72·0	61·0	30·0	16·0	...	43·0	197·0	...	...	...	43·0	36·0	3·0	6·0
February......	72·0	49·0	76·0	25·5	93·0	12·0	26·0	17·0	177·0	...	...	...	...	10·0	...	49·0
March.........	39·0	10·0	...	6·0	...	7·0	12·0	16·0	507·0	461·0	...	5·0	133·0	10·0	2·0	9·5
April	88·5	27·0	158·0	1·5	136·5	...	...	...	157·0	271·0	...	...	14·0	20·5	12·5	30·0
May	...	13·0	33·0	...	75·0	17·0	0·5	31·5	172·0	415·0	...	...	27·5	1·0		
June	9·0	67·5	41·0	13·5	22·5	15·0	...	47·5	123·0	226·5	16·0	...	...	35·0	10·0	45·0
July	97·0	35·0	...	...	...	...	...	...	43·5	117·5	39·5	...	16·0	46·0	134·5	47·5
August	87·0	11·5	...	...	9·0	...	...	2·0	32·5	630·0	21·0	...	11·0	60·5	11·0	97·0
September ...	2·0	22·0	6·5	9·0	227·5	3·0	16·0	21·0	470·2	380·5	100·0	...	...	15·5	21·0	20·0
October	...	148·0	37·0	8·0	6·5	...	10·5	33·5	588·5	18·0	...	...	135·0	46·0	13·5	45·0
November ...	27·0	7·0	3·5	6·5	47·5	35·5	12·0	46·5	189·0	280·5	108·0	3·5	98·0	...	9·9	35·0
December ...	38·0	19·0	44·0	...	41·0	...	...	...	341·5	80·0	...	9·0	220·0	37·0	4·0	17·0
Sums......	751·5	433·0	471·5	131·0	688·5	105·5	77·0	258·0	2998·2	2880·0	284·5	17·5	697·5	317·5	220·5	401·5

TABLE II.

Showing the Amount of Wind for the year 1842.

Months.	N.	N.N.E.	N.E.	E.N.E.	E.	E.S.E.	S.E.	S.S.E.	S.	S.S.W.	S.W.	W.S.W.	W.	W.N.W.	N.W.	N.N.W.
January	8·0	64·0	27·0	57·0	25·5	...	...	75·5	107·0	109·0	...	16·0	...	68·5	23·0	34·5
February......	...	...	...	...	168·5	6·5	...	13·5	527·5	143·0	...	...	18·0	...	...	3·0
March.........	43·0	77·5	...	34·0	6·0	2·0	7·0	40·0	551·5	259·0	...	...	53·5	195·0	64·0	69·5
April	18·5	53·0	209·5	364·5	395·5	7·5	18·5	18·5	...	6·0	...	...	..	...	28·0	10·0
May	19·0	...	...	...	24·0	...	2·0	18·0	269·3	444·5	11·0	...	35·0	25·0	2·0	13·0
June	8·0	52·5	...	12·0	224·5	...	...	...	166·5	178·5	...	...	...	23·0		
July	14·5	119·0	...	...	138·0	12·0	3·0	...	184·0	281·0	...	...	58·5	19·5		
August	36·0	58·0	92·0	17·5	57·5	...	...	...	16·5	256·0	...	...	18·0	...		
September ...	78·5	...	...	52·8	23·5	...	...	...	48·5	114·5	...	...	53·5	107·0	...	24·5
October	41·5	91·0	1·5	105·0	212·5	...	...	...	43·5	...	...	...	22·5	95·0	67·5	33·0
November ...	...	...	114·5	117·5	63·5	69·0	60·0	25·5	942·5	221·5	160·0	...	23·0	47·0	...	22·5
December ...	...	...	...	...	51·5	...	11·0	24·0	373·0	95·5	...	...	27·5	8·0		
Sums......	267·0	515·0	444·5	760·3	1390·5	97·0	101·5	215·0	3229·8	2108·5	171·0	16·0	309·5	588·0	184·5	210·0

TABLE III.

Showing the Amount of Wind for the year 1843.

Months.	N.	N.N.E.	N.E.	E.N.E.	E.	E.S.E.	S.E.	S.S.E.	S.	S.S.W.	S.W.	W.S.W.	W.	W.N.W.	N.W.	N.N.W.
January	69·5	41·0	...	...	47·5	...	6·5	...	152·0	218·0	8·5	...	115·5	152·5	23·5	27·5
February......	...	28·0	198·5	282·0	42·5	...	29·0	...	137·5	5·0	5·0	...	...	...	...	14·0
March..........	...	...	...	...	396·0	151·5	...	28·0	167·5	201·5	...	...	4·5	...		
April	5·0	36·0	47·5	2·5	68·0	...	2·0	3·0	165·7	308·5	17·5	...	...	62·5	61·0	4·0
May	39·0	7·0	9·5	...	130·0	...	12·0	68·5	233·0	32·0	...	...	...	20·0	61·0	30·0
June	5·0	2·5	2·5	...	57·5	24·5	32·0	...	27·0	357·0	...	...	...	36·0	17·5	2·0
July	104·0	126·5	...	...	...	...	...	...	66·5	143·0	64·5	5·0	52·5	12·0	...	32·5
August	48·5	14·0	35·5	...	20·5	7·5	...	...	7·0	364·5	23·0	...	2·0	22·0		
September ...	37·5	49·0	15·0	11·5	137·0	16·5	...	..	10·0	51·5	...	...	3·0	28·0	...	5·0
October	68·0	...	62·0	...	...	...	...	10·0	152·0	227·0	...	...	...	142·5	24·0	50·0
November ...	41·0	...	26·0	...	9·0	...	...	106·0	246·0	447·5	...	...	3·0	26·0	16·0	
December ...	12·0	2·0	...	...	...	...	...	...	114·5	402·0	4·0	...	...	21·0	...	
Sums......	429·5	306·0	396·5	296·0	908·0	200·0	81·5	215·5	1478·5	2757·5	122·5	5·0	180·5	522·5	203·0	165·0

TABLE IV.

Showing the Mean Amount of Wind for the three years—1841, 1842, 1843.

Years.	N.	N.N.E.	N.E.	E.N.E.	E.	E.S.E.	S.E.	S.S.E.	S.	S.S.W.	S.W.	W.S.W.	W.	W.N.W.	N.W.	N.N.W.
1841.	751·5	433·0	471·5	131·0	688·5	105·5	77·0	258·0	2998·2	2880·0	284·5	17·5	697·5	317·5	220·5	401·5
1842.	267·0	515·0	444·5	760·3	1390·5	97·0	101·5	215·0	3229·8	2108·5	171·0	16·0	309·5	588·0	184·5	210·0
1843.	429·5	306·0	396·5	296·0	908·0	200·0	81·5	215·5	1478·5	2757·5	122·5	5·0	180·5	522·5	203·0	165·0
Sums ...	1448·0	1254·0	1312·5	1187·3	2987·0	402·5	260·0	688·5	7706·5	7746·0	578·0	38·5	1187·5	1428·0	608·0	776·5
Means...	482·7	418·6	437·5	395·7	995·7	134·1	86·7	229·5	2568·8	2582·0	192·7	12·8	395·8	476·0	202·7	258·8

TABLE V.

Showing the Reduction to eight Points of the Compass from Table IV.

Years.	N.	N.N.E.	N.E.	E.N.E.	E.	E.S.E.	S.E.	S.S.E.	S.	S.S.W.	S.W.	W.S.W.	W.	W.N.W.	N.W.	N.N.W.
1841.	...	...	187·0	113·5	...	...	...	...	2246·5	2447·0	...	...	9·0	212·0	143·5	143·5
1842.	...	...	273·5	744·3	1081·0	...	...	5·0	2962·8	1593·5	...	...	...	491·0	83·0	
1843.	...	...	274·0	291·0	727·5	...	...	50·5	1049·0	2451·5	...	...	...	322·5	121·5	
Sums ...	...	...	734·5	1148·8	1080·5	...	...	55·5	6258·3	6492·0	...	...	9·0	1025·5	348·0	143·5
Means...	...	...	244·8	382·9	602·8	...	...	18·5	2086·1	2164·0	...	...	3·0	341·8	116·0	47·8

TABLE VI.

Showing the Reduction of the mean Results to eight Points.

N.	N.N.E.	N.E.	E.N.E.	E.	E.S.E.	S.E.	S.S.E.	S.	S.S.W.	S.W.	W.S.W.	W.	W.N.W.	N.W.	N.N.W.
		244·8	382·9	599·8	...	...	...	2086·1	2164·0	...	...	...	341·8	116·0	29·3

TABLE VII.

Showing the mean Quantity of Wind for the Four Seasons.

Seasons.	N.	N.N.E.	N.E.	E.N.E.	E.	E.S.E.	S.E.	S.S.E.	S.	S.S.W.	S.W.	W.S.W.	W.	W.N.W.	N.W.	N.N.W.
Spring......	84·0	74·5	152·5	136·2	410·3	61·7	18·0	74·5	741·0	799·5	9·5	1·7	89·2	111·3	76·8	55·3
Summer ...	136·3	162·2	57·0	14·3	176·5	19·7	11·7	16·5	222·2	851·3	54·7	1·7	52·7	84·7	57·3	74·7
Autumn ...	98·5	105·7	88·7	103·4	242·3	41·3	32·8	80·8	896·7	581·3	122·7	1·2	112·7	169·0	50·3	78·3
Winter ...	163·8	75·7	139·1	141·8	166·5	11·5	24·2	57·7	709·0	350·8	5·8	8·3	141·3	111·0	17·8	50·3

TABLE VIII.

Showing the Reduction of Table VII. to eight Points of the Compass.

Seasons.	N.	N.N.E.	N.E.	E N.E.	E.	E.S.E.	S.E.	S.S.E.	S.	S.S.W.	S.W.	W.S.W.	W.	W.N.W.	N.W.	N.N.W.
Spring	...	...	143·0	134·5	321·1	...	...	19·2	657·0	725·0	...	...	...	49·6	58·8	58·2
Summer	...	...	2·3	12·6	123·8	...	...	...	85·9	689·1	...	...	...	65·0	45·6	
Autumn	...	...	...	102·2	129·6	...	...	2·5	798·2	475·6	34·0	...	...	127·7	17·5	
Winter	...	...	133·3	133·5	25·2	...	6·4	7·4	545·2	275·1	...	...	...	99·5		

TABLE IX.

Showing the Amount of Wind for Two Months of 1844.

Months.	N.	N.N.E.	N.E.	E.N.E.	E.	E.S.E.	S.E.	S.S.E.	S.	S.S.W.	S.W.	W.S.W.	W.	W.N.W.	N.W.	N.N.W.
January	15·15	4·6	...	0·50	5·20	...	...	...	11·50	11·10	...	...	0·8	3·5	3·9	15·2
February......	3·6	12·6	6·5	7·8	...	...	...	...	...	34·8	1·5	3·0	...			
Sum	18·75	17·2	6·5	8·3	5·2	...	...	...	11·5	45·9	1·5	3·0	0·8	3·5	3·9	15·2

TABLE X.

Showing the Effective Winds in the Order of following Points of the Compass.

1841.	1842.	1843.	Mean.
2447·0 S.S.W.	1593·5 S.S.W.	2451·5 S.S.W.	2164·0 S.S.W.
2246·5 S.	2962·8 S.	1049·0 S.	2086·1 S.
113·5 E.N.E.	5·0 S.S.E.	50·5 S.S.E.	599·8 E.
187·0 N.E.	1081·0 E.	727·5 E.	382·9 E.N.E.
143·5 N.N.W.	744·3 E.N.E.	291·0 E.N.E.	244·8 N.E.
143·5 N.W.	273·5 N.E.	274·0 N.E.	29·3 N.N.W.
212·0 W.N.W.	83·0 N.W.	121·5 N.W.	116·0 N.W.
9·0 W.	491·0 W.N.W.	322·5 W.N.W.	341·8 W.N.W.

TABLE XI.

Showing the Comparative Indications of Lind's Gauge and Whewell's Anemometer.

Experiments.	Pressure and Velocity of Wind by Lind's Gauge.			Whewell's Anemometer.		Differences.
	Altitude of Column. Mean.	Pounds on Foot Square.	Feet per Second.	Space described in One Hour.	Velocity of Wind to Velocity of Fly.	
1	0·05	0·260	10·68	1·0	10·6	
2	0·06	0·312	11·68	1·5	7·8	2·8
3	0·08	0·417	13·5	2·0	6·7	1·0
4	0·10	0·541	15·3	2·5	6·6	0·6
5	0·13	0·70	17·5	3·0	5·8	0·3
6	0·16	0·83	19·1	3·5	5·5	0·3
7	0·19	1·00	21	4·0	5·2	0·3
8	0·22	1·17	22·6	4·5	5·0	0·2
9	0·27	1·4	24·6	5·0	4·9	0·1
10	0·29	1·56	26·14	5·5	4·75	0·1
11	0·33	1·72	27·5	6·0	4·5	0·2
12	0·35	1·82	28·26	6·5	4·3	0·2
13	0·4	2·0	30·17	7·0	4·3	0·0
a	*b*	*c*	*d*	*e*	*f*	*g*

TABLE XII.

Showing the Effective Winds of each Month reduced to eight following Points of the Compass.

Months.	S.S.W.	S.	S.S.E.	S.E.	E.S.E.	E.	E.N.E.	N.E.	N.N.E.	N.	N.N.W.	N.W.	W.N.W.	W.	W.S.W.	S.W.
January	66·0	29·0	16·8	...	...	...	34·0	30·2	...	...	...	14·5	80·4	18·4		
February......	23·9	256·7	...	18·3	2·9	95·3	102·5	89·8	...	...	12·0	...				
March.........	278·0	381·6	1·7	...	...	70·3	11·6	...	...	...	...	15·7	14·8			
April	156·5	70·2	...	...	...	195·3	122·8	132·5	...	...	7·6	27·0	25·1			
May	290·5	205·4	25·0	...	...	55·5	...	10·4	...	...	...	16·2	9·7			
June	213·2	98·2	...	1·5	...	101·5	8·5	9·2	...	...	...	...	18·2			
July	87·0	26·2	...	...	...	3·3	...	...	...	...	26·7	43·8	21·8	...	1·7	34·7
August	389·0	...	...	...	...	18·7	5·8	27·8	...	38·4	32·3	3·7	25·0			
September ...	158·4	137·0	...	...	...	110·5	24·4	...	...	...	9·5	1·7	43·6	...	...	26·2
October	2·0	224·5	...	...	...	20·5	37·7	33·5	...	...	28·3	31·5	94·5			
November ...	314·2	436·4	40·2	15·7	10·5	...	40·2	...	...	...	...	...		1·3	...	41·3
December ...	185·5	259·7	2·3	2·4	...	...	...	13·4	...	...	...	...	22·0	51·7	3·0	
Total......	2164·0	2125·0	86·0	37·9	13·4	671·0	387·5	346·8	...	38·4	116·4	154·1	355·1	71·4	4·7	102·2

The results are reduced to eight points in Table VI.

TABLE XIII.

Showing the Effective Winds for the Four Seasons.

Spring.	Summer.	Autumn.	Winter.
725·0 S.S.W.	689·1 S.S.W.	475·6 S.S.W.	275·1 S.S.W.
657·0 S.	85·9 S.	798·2 S.	545·2 S.
19·2 S.S.E.	123·8 E.	2·5 S.S.E.	7·4 S.S.E.
321·1 E.	12·6 E.N.E.	129·6 E.	6·4 S.E.
134·5 E.N.E.	2·3 N.E.	102·2 E.N.E.	25·2 E.
143·0 N.E.	58·2 N.N.W.	17·5 N.W.	133·5 E.N.E.
58·8 N.W.	45·6 N.W.	127·7 W.N.W.	133·3 N.E.
49·6 W.N.W.	65·0 W.N.W.	34·0 S.W.	99·5 W.N.W.

TABLE XIV., showing the mean Results of Osler's Anemometer at Devonport for the years 1841 and 1842.

1841.	N.	N.N.E.	N.E.	E.N.E.	E.	E.S.E.	S.E.	S.S.E.	S.	S.S.W.	S.W.	W.S.W.	W.	W.N.W.	N.W.	N.N.W.
Sums of forces (a)	68·7	12·0	89	16·4	700	44	341·5	133	593	289	707·8	179·2	390	149·5	413·3	82·7
Number of observations (b)	30	4	48	9	197	33	144	79	237	130	250	81	177	84	231	45
Mean force $= \frac{a}{b}$	2·29	3	1·85	1·82	3·5	1·33	2·37	1·68	2·5	2·22	2·83	2·21	2·2	1·77	2·65	1·8
Velocity in miles per hour (c)	21·5	24·7	19·4	19·23	26·5	16·4	21·7	18·47	22·54	21·24	23·98	21·2	21·1	18·96	23·18	19·12
Total number of hours (d)	400	106	267	80	430	241	590	273	780	390	772	320	780	530	1390	330
Integral effect $= c \times d$	8600	2618	5179	1538	11395	3952	12803	5042	17581	8283	18512	6784	16458	10048	32220	6309
1842.																
Sums of forces (a)	32	47·5	43·8	19·5	70·5	17·5	191	232	519·3	152·3	564	182·8	196·5	309·5	542	42·3
Number of observations (b)	32	34	29	19	57	24	114	91	170	72	168	71	102	80	136	34
Mean force $= \frac{a}{b}$	1	1·4	1·5	1·02	1·24	0·73	1·68	2·55	3·05	2·1	3·357	2·57	1·926	3·86	3·98	1·244
Velocity in miles per hour (c)	14·258	16·87	17·4	14·4	15·87	12·19	18·47	23	25	20·66	26·12	22·8	19·77	27·8	28·4	15·9
Total number of hours (d)	479	255	430	170	468	340	622	500	680	360	635	270	435	460	1000	464
Integral amount $= c \times c$	6829	4289	7482	2448	7427	4144	11488	11500	17000	7437	16586	6156	8599	12788	28400	7377

TABLE XV., showing the mean Results of Osler's Anemometer at Greenwich for the years 1841 and 1842.

1841.	N.	N.N.E.	N.E.	E.N.E.	E.	E.S.E.	S.E.	S.S.E.	S.	S.S.W.	S.W.	W.S.W.	W.	W.N.W.	N.W.	N.N.W.
Sums of forces (a)...............	404·5	81·5	72·75	430·7	43·25	3·5	4·75	137	403·7	1104	1191·7	889·5	321·5	118·7	136·2	197·7
Number of observations (b) ...	194	40	49	118	23	4	7	71	187	417	486	379	160	63	55	82
Mean force = $\frac{a}{b}$	2	2	1·48	3·65	1·88	0·875	0·68	1·93	2·16	2·64	2·45	2·37	2·0	1·88	2·47	2·4
Velocity in miles per hour (c)	20·56	20·16	17·34	27·23	19·54	13·33	11·75	19·8	20·94	23·17	22·31	21·7	20·16	19·54	22·4	22·0
Total number of hours (d) ...	418	136	240	234	204	74	78	136	508	684	1196	808	798	220	200	164
Integral effect = $c \times d$.........	8594	2768	4161	6371	3987	986	916	2692	10637	15848	26682	17541	16087	4298	4480	3608
1842.																
Sums of forces (a)...............	174·5	78	153·7	93·7	68	1·25	20	68·5	139	400	1244	819	224	102·5	64	102
Number of observations (b) ...	118	68	114	61	58	3	9	40	86	234	481	348	96	35	29	57
Mean force = $\frac{a}{b}$	1·47	1·14	1·35	1·53	1·17	0·417	2·22	1·7	1·61	1·71	2·58	2·35	2·33	2·93	2·2	1·79
Velocity in miles per hour (c)	17·28	15·22	16·56	17·63	15·42	9·2	21·24	18·59	18·1	18·63	22·9	21·85	21·76	24·4	21·14	19
Total number of hours (d) ...	482	168	454	210	438	62	30	46	480	432	916	792	538	118	86	142
Integral result = $c \times d$	8329	2557	7518	3702	6754	570	637	855	8688	8048	20976	17805	11706	2879	1818	2698

Report on Atmospheric Waves. *By* W. R. Birt.

The British Association, at its last meeting, having entrusted me, under the superintendence of Sir John Herschel, with the further investigation of atmospheric waves, I immediately entered on the inquiry, and now present the following report of the progress I have made during the past year. It consists, first, of the copy of a letter addressed by me to Sir John Herschel, in which is detailed the plan on which I have proposed to examine these interesting atmospheric movements, a list of the stations from which I have obtained observations, and the conclusions which I have drawn from a discussion of them; second, of remarks on the waves and their phases as they passed the several stations; third, an examination of barometric curves having the spaces between them coloured to exhibit the slope or dip of the atmosphere between the stations; fourth, an explanation of sections of waves in various directions; and fifth, of additional remarks drawn up after the preceding were finished.

Cambridge House Academy, Cambridge Road, Bethnal Green,
London, August 10th, 1844.

Dear Sir,—Since the last meeting of the British Association, I have endeavoured to collect materials for the purpose of determining the extent, direction of motion, and velocity of the atmospheric waves. Several heads of inquiry have suggested themselves to me, such as the progress of large waves similar to that observed by myself in November 1842, an examination of nodal points at Brussels, lines of contemporaneous elevation, or those lines that at any particular period may possess a similarity of pressure, and other subjects of a more restricted interest. In order to assist in this inquiry, you most kindly lent me observations made in Russia, Prague, and other parts of Europe. Mr. Airy has most obligingly furnished me with the volume of 'Observations made at Greenwich during 1840, 1841,' and I have obtained observations from other localities. Some of the Russian observations I have projected in curves, from which I obtain the same evidence of the progression of the wave as from the discussion of the quarterly observations. I have also projected and compared a few curves at Greenwich and Prague. These at present are too few and the stations too far apart to admit of scarcely any results beyond the motions of the waves; there are however two periods which promise some very interesting results,—the Equinoctial observations of September 1841, from about sixty stations, and the great November wave of 1842. The latter I have paid the greatest attention to, as from its symmetry and the conclusive evidence we have of its motion from Dublin to Munich, it appeared to promise a rich harvest of results. The stations I have obtained observations from during November 1842, are as per accompanying list:—

England.

Longstone.
York.
Haisboro.
London.
Greenwich.
Canterbury.
Hastings.
St. Catherine's Point.
Scilly.
South Bishop.
Bardsey.
Birmingham.

Ireland.

Dublin.

Scotland.

Makerstoun.
Glasgow.

Continental.

Heligoland.
Brussels.
Gratz.
Carlsruhe.
Munich.
Prague.

Continental.
Milan.
Naples.
Great St. Bernard.
Geneva.
Paris.

Colonial.
Toronto.
St. Helena.
Cape of Good Hope.
Van Diemen's Land.

In the spring of the present year, the Honourable the Corporation of the Trinity House allowed me most obligingly free access to the barometrical records kept at certain lighthouses, and I obtained observations made at the following stations:—Longstone, coast of Northumberland; Heligoland; Haisboro, coast of Norfolk; St. Catherine's Point, Isle of Wight; Scilly; South Bishop; and Bardsey Island, coast of Wales. The plan I propose for thoroughly examining the wave is this:—

I. To reduce all the observations to the level of the sea; this I apprehend is the only efficient test that can be brought to bear on the theory that the non-periodic oscillations of the barometer are due to waves; for if we contemplate a *single* wave, a barometer at the station over which the apex passes at any given time, will exhibit a greater pressure than any of those at other stations, and the slope to the other stations will be greater or less according as they are situated on, or at any angle to, the transverse or longitudinal sections of the waves.

II. To ascertain the difference of such reduced pressures between *all* the stations, and to exhibit such differences on a diagram of the area over which the stations extend. By this means I apprehend a more accurate idea can be formed of the *disposition* of the atmosphere than the curves will afford, and the highest and lowest points may be readily seen. As the lighthouse observations are taken every six hours, I propose constructing four such diagrams for each day from the 8th to the end of November, and, as I find it necessary; to colour certain portions of the areas indicating the progress of the waves *.

III. When necessary, to construct models with a view to approximate to the slopes of the waves, and particularly to mark the directions of the crests and troughs, the maxima and minima.

IV. With the assistance of the above-named diagrams and models, to project sections of the waves taken in various directions, from which, should the area be sufficiently extensive, the spans and altitudes may be approximately deduced.

V. To select the most advantageous lines from the area, and to project the curves obtained at stations situated on or near such lines on the same sheet, and referred to the same normal altitude, 29·500 for instance. The spaces between each curve to be coloured, the same colour to be continually *under* the same curve. These coloured projections will indicate three things as connected with the *disposition* of the atmosphere;—1st, the depth or extent of colour will show the depression of the lower station below the upper; 2nd, the intersections of the curves will indicate that at the time of intersection the stations had an equality of pressure; and 3rd, the change of the position of the same colour will point out that the station which exhibited or experienced the higher or lower pressure, afterwards experienced the lower or higher, with its amount †.

In this manner I have commenced the discussion of the observations now in hand, and as the depression of the 11th November appears to be the commencement of the large wave, I have thought it best to study the *disposition* of the atmosphere over the area a few days previous, in order to obtain the

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* See Plate XLII.

† See Plate XLIII.

true character of the depression. The result of this portion of my investigation is, that during the 8th and 9th of November *two* systems of waves were traversing the British Isles and the neighbouring parts of Europe, the largest from the N.W. and the smallest from the S.S.W. A trough belonging to the largest system extended from Scilly to Longstone, or, as shown by the model, in a line to the S.E. of this. A well-marked wave of the second system passed over on the 9th from Scilly to Longstone; the altitude varied according to the *disposition* of the atmosphere arising from the first wave from 29·537 at Bardsey to 29·590 at Longstone*. From a very careful examination of the passage of this wave over the area, it appears that its transverse section extended over 341 miles with an altitude of ·090 inch. This wave progressed at the rate of twenty-five miles per hour. The great depression from Geneva to Longstone appears to be connected with, or result from, a permanent depression in the north-west of England, or a gradual diminution of pressure from the central part of Europe; and it is probable that the nodal character of Brussels may depend on its enjoying permanently a greater pressure than the stations to the north-west of it, and that it is only very high waves, such as that of the 18th November, that are capable of depressing Brussels below stations situated in the atmospheric valley, as Dublin. It is remarkable, that in all large storms the barometer is more depressed in the central part of England. It appears that the maximum, or the apex of the wave succeeding the trough of the first system, was comparatively small, appearing only as a bulge on the posterior slope of a large wave. This however will be better determined by the further examination of the curves.

I apprehend I have thus obtained a starting-point from which the true character of the wave or waves from the 11th to the 25th November may be determined, and the agreement or anomalies of the curves explained. I have accompanied this communication with specimens of the tables I intend to construct, the diagrams of the areas (these are at present imperfect, owing to *all* the stations not having been inserted), models to assist in obtaining an idea of the *disposition* of the atmosphere, sections of the waves projected from observations reduced to the level of the sea, and the projected curves with the spaces between them coloured as before mentioned. I shall endeavour to execute, by the meeting of the Association, the continuation of these and other curves past the depression of the 11th, with their appropriate colours; but I fear I shall not be able to obtain any further results by that time than those already mentioned in this communication. I have also inclosed copies of remarks I have made with a view to explain the drawings and models, and to illustrate the manner in which I pursue the inquiry.

These remarks and explanations I do not by any means consider in the present state of the inquiry as final; I have used them merely to assist in obtaining an idea of the nature of the barometric fluctuations within the area and at the times named, with the view of clearly understanding the nature of the great depression of the 11th. You will perceive I have scarcely touched on any of the continental stations; and as I more fully investigate their curves and sections, many of the views recorded in the remarks, &c. will doubtless require modification. I am inclined however to consider the two systems as clearly made out, and that the form, direction, and velocity of wave B 1 has been tolerably well apprehended. I have left blank leaves in writing the remarks and explanations, for any notes or suggestions you may feel desirous of inserting.

You will probably notice the progress I have made, or rather the plan I

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* At Scilly the altitude of the maximum was 29·645.

intend to pursue, in the report of the Committee for Magnetical and Meteorological Co-operation. When you allude to it, may I respectfully solicit your kindness to inquire if the Association will favour me with extracts from Mr. Snow Harris's 'Hourly Observations of the Barometer at Plymouth for November 1842,' and from Sir David Brewster's 'Observations,' I believe at Inverness and Kingussie, for the same month? The first station will be exceedingly important in the south-western part of the area, and Sir David's will furnish some valuable information relative to the progress of the waves further north than Longstone. I am exceedingly anxious to obtain barometric records for this month, November 1842, from Ireland and Scotland.

I have inclosed the copy of Lamont's 'Annalen,' No. 4, which you kindly lent me, and for which I beg you will accept my best thanks. If you can favour me with a few copies of the 'Report on the Reduction of Meteorological Observations,' I shall feel obliged. Col. Sabine advised me to have some printed, but I found the type had been broken up.

I have the honour to be, dear Sir,
Yours very respectfully,
Sir John F. W. Herschel, Bart. W. R. Birt.

Remarks on Atmospheric Waves.

Stations of Observation.

Heligoland.
Longstone.
Haisboro.
Brussels.
Geneva.
St. Catherine's Point.
Birmingham.
Bardsey Island.
Dublin.
South Bishop.
Scilly.

(1.) From a careful study of the altitudes of the barometer observed at the stations above-enumerated when reduced to the level of the sea, I am inclined to believe that the area included by the extreme stations was traversed at the commencement of the observations by *two* systems of waves. The axes of translation of these systems formed a considerable angle; one appeared to have a N.W.—S.E. direction, the other S.S.W.—N.N.E. I am also inclined to consider that a permanent depression of the atmosphere from Geneva to the centre of England exists; or should this be found not to be the case, the phænomena observed most probably result from the passage of a normal wave or waves of very extensive magnitude. The projection of the barometric altitudes in curves (the abscissæ representing the times) clearly indicates the passage of vast waves, but the only efficient test of this indication consists in obtaining sections of such waves, or projecting curves, in which the distances of the stations are considered as abscissæ. Now as it is difficult to obtain stations (especially when the observations have not been made with a view to this particular inquiry), situated in a right line and sufficiently numerous for the purpose, but by constructing models from the curves obtained by a combination of all the stations, a tolerable idea may be formed of the *disposition* of the atmosphere over the whole area; and from a succession of such models, illustrated by curves in particular directions and carefully studied with reference to the curves obtained from the times as abscissæ, the passage of these waves can be clearly made out, and, I apprehend, their magnitudes tolerably well ascertained. In the following inquiry I shall term the system of waves flowing from the N.W. A, and that flowing from the S.S.W. B; each particular wave will be designated A 1, A 2, &c., B 1, B 2, &c.

(2.) Wave A 1.—A line cutting the crest of the wave A 1 transversely appears to have passed through Geneva and Brussels, and a continuation of this line would pass to the north-east of Longstone; the highest blue curve *a* in fig. 2, Plate XLIV., will give the approximate form of the slope of this part of the wave, Nov. 8.21 hours. At 8.15, six hours earlier, a line joining Scilly and St. Catherine's Point appeared to be somewhat parallel to the crest of the wave; the slope could not have extended much further than Dublin, the slope from Dublin to Longstone being only ·093.

(3.) Wave B 1 appears to have flowed from Scilly towards Longstone; the highest blue curve *a*, in fig. 1, Plate XLIV., will give an approximate form of the slope of this part of the wave (or rather the *form* of the atmosphere on this line, arising from a combination of the two waves, A 1 and B 1), for at 8.15 the remarkable bulge in the neighbourhood of South Bishop appears to have been a portion of wave A 1, which at that time was passing South Bishop from the N.W.*

(4.) Nov. 8.21.—Wave A 1. The highest blue curve *a*, in fig. 2, Plate XLIV., gives the approximate form of the slope of this wave from Geneva to Brussels. The highest blue curve *a*, in fig. 3, gives an approximate section of this wave from Brussels to Dublin, crossing the section of wave B 1, in fig. 1, at 01 in fig. 3. Dublin is now at a minimum†. The bulge which characterized the line from Scilly to Longstone in fig. 1, curve *a*, appears very conspicuously in this curve between Birmingham and Dublin. The three curves in fig. 3 exhibit the variations in the pressure at the stations Brussels, Birmingham and Dublin; during the twelve hours from Nov. 8.21 to 9.9, the bulge appears to be peculiar to Birmingham; and the minimum, as it advances, appears to *run up* the slope, and not to pass onwards at the same level.

(5.) Wave B 1.—The progression of the bulge towards the S.E. left the gradual and gentle slope as exhibited in fig. 1, curve *b*, Plate XLIV., and this either formed a portion of the slope of wave A 1, or of a normal wave, or resulted from the permanent depression before alluded to. It is worthy of remark, that the fall of the slope accompanies the progression of wave A 1‡.

(6.) Model for this term gives a general idea of the slope of wave A 1, from a line joining Brussels and Heligoland to a line joining Dublin and Longstone.

(6*.) Nov. 9.2.—Dublin and Bardsey at the same level, the atmosphere rising to South Bishop and Scilly, and dipping to Longstone; this equality of level is occasioned by the passage of the trough of A 1. See coloured diagrams, fig. 2, Plate XLIII., intersection of Dublin and Bardsey curves, near *m*.

(7.) Nov. 9.3.—The minimum has now passed Dublin, and a trough exists between Dublin and St. Catherine's Point; minima now exist at Longstone, Bardsey Island, South Bishop, and Scilly, so that the trough of the advancing wave A 1 extends in the line from Scilly to Longstone, with a dip of ·369 to Longstone. The minima at Longstone, Bardsey, and South Bishop, appear to be produced by the posterior trough of A 1, and the minima at Scilly and Geneva by the anterior trough of B 1, see Plate XLII.; if so, the curve *c*, fig. 1, Plate XLIV., must exhibit, not the anterior slope of B 1, but a slope

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* From the consideration that the minimum at Scilly at 9.3 was occasioned by the anterior trough of B 1, the curve *a*, fig. 1, could not have represented any portion of the anterior slope of this wave. It is most probable that the curve resulted from a combination of the slope of A 1 with the bulge, and the slope arising from the permanent depression. See (5) and (7).

† The observed minimum occurred at Dublin Nov. 9.1.0.

‡ At this time wave B 1 had not entered on the area.

arising from the permanent depression before noticed, a normal wave, or from A 1. See (5.) A slight rounding of this curve is seen very near Longstone, and the depression between it and Scilly is developed as the wave B 1 advances. The curve at 9.15 *e* exhibits the crest of wave B 1 passing South Bishop, and indicates the wave to be very small. The blue curves on all the lines are descending; this would result from the passage of the posterior slope of A 1. The curves ascend as the anterior slope of B 1 approaches: this is found to be the case Nov. 9.9, Scilly to Longstone and Geneva to Brussels. Brussels does not exhibit this rise, as neither the trough of A 1 nor the apex of B 1 has arrived at this station.

(8.) Wave A 1.—The trough of this wave is now passing Longstone, Bardsey, and South Bishop; the bulge at or near Birmingham is lessened, and it begins to appear eastward of Haisboro (see curves *b b*, figs. 3 and 2, Plate XLIV.). We have thus satisfactorily traced the progression of this bulge from the north-west, past South Bishop, and also in the neighbourhood of Haisboro; there can be no question that its longitudinal direction was considerable, but we have not at present sufficient data for determining it.

(9.) Wave B 1.—The anterior trough of this wave now enters on the area and passes Geneva and Scilly; the wave also enters, producing a rise of the barometer, at both stations.

(10.) Wave A 2 (or shoulder).—This wave has now entered on the area 72 miles (from Dublin to Bardsey); the extremity of the curve *b*, fig. 3, Plate XLIV., tinted red, shows the barometric rise due to this wave.

(11.) Nov. 9.3.—Model exhibits the general slope of A 1 (or normal) in the same direction as before; the trough between Dublin and Birmingham is brought fully into view.

(12.) Nov. 9.5.—Dublin attains the altitude of South Bishop, and the two curves continue nearly identical for the next nine hours; Dublin rising from the anterior slope of A 2, combined with that of B 1 and South Bishop, principally from the latter wave (see coloured diagrams, fig. 2, Plate XLIII.).

(13.) Nov. 9.9.—Wave A 1, fig. 3, curve *c*, Plate XLIV. As wave B 1 advances, the anterior slope will occasion a rise, while the barometer is falling from the passage of the posterior slope of the wave A 1. This is particularly observable at Birmingham, and a secondary trough is occasioned in consequence between this station and Brussels. The normal slope is however clearly seen, for the minimum, which now is situated a little north-west of Birmingham, is considerably above the level of the minimum of the last term.

(14.) The bulge, which towards the north-east assumes a more gentle and flowing character, passes beyond Brussels towards Geneva at this term; this is exhibited in curve *c* (red) of fig. 2, Plate XLIV.

(15.) Wave B 1.—The crest of this wave passes over Scilly, and at the same moment its anterior trough passes St. Catherine's Point; the half-breadth cannot therefore extend much beyond South Bishop, or about 150 miles. From the red curve *d*, in fig. 1, Plate XLIV., it would appear to form a part of the slope of the depression before-mentioned. Since the passage of the posterior trough of A 1 at Longstone, Nov. 9.3., the barometer has risen at this station from the anterior slope of A 2 alone, amount ·099. As this slope passes over Longstone, the anterior trough of B 1 becomes more conspicuous on the slope of the depression, and is fully developed next term.

(16.) Nov. 9.9.—Model. The approach of the trough of A 1 is clearly seen on the model for this term, also its direction as it cuts a line joining St. Catherine's Point, Bardsey and Dublin obliquely, and is at right angles to a line joining Geneva and Brussels. According to this view, it would appear that the trough had made no progress since Nov. 9.3*. I am however inclined to consider that, as it passed Bardsey at this epoch (Nov. 9.3.), it would have passed the intersection of the line from Birmingham to South Bishop at 9. It is probable that the altitude at the point of intersection should be less than given in the model; if so, the two troughs, posterior A 1 and anterior B 1, would nearly coincide, and Bardsey being the nearest station of observation, would give the lowest reading. Upon this view we shall have the flowing on of the two waves; the rise at Scilly from 3 to 9, being produced by the joint action of waves A 2 and B 1, and that at South Bishop also, while at Bardsey the rise from 3 to 9 is due only to the anterior slope of A 2, and B 1 does not occasion any rise at this station until after 9 hours. The superiority of the Dublin to the Bardsey curve, Plate XLIII., fig. 2, indicates that the two stations are situated under the anterior slope of A 2. Upon comparing this model with the two former, the approach of the area to a level is very apparent, although the slope is generally in the same direction as in the former models.

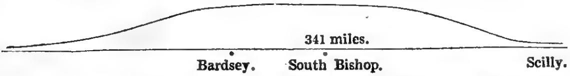
(17.) Nov. 9.9.—St. Catherine's Point and Scilly approach nearly to a level, as the trough of B 1 passes St. Catherine's while the maximum is passing Scilly. See (15.) The curve at St. Catherine's Point, fig. 2, Plate XLIII., exhibits a very small rise; probably the trough of A 1 has tended to depress the maximum of B 1.

(18.) Nov. 9.13.30 (about).—Scilly, South Bishop and Dublin at the same level with South Bishop near its maximum.

(19.) Nov. 9.15.—Wave A 1. The trough of this wave appears to be still between St. Catherine's Point and Dublin.

(20.) Wave B 1.—The apex of this wave now passes over St. Catherine's Point and Bardsey. Curve *e* (red †), fig. 1, Plate XLIV. exhibits this apex, also the anterior trough between Bardsey and Longstone noticed in (15.).

The annexed figure represents an approximate transverse section of wave B 1 as it passed South Bishop and Bardsey.



Altitude of wave ·090 measured from the slope from Scilly to Longstone.

(21.) Nov. 9.15.30.—Scilly and Bardsey on a level, with South Bishop rising between them. Dublin is still rising, most probably from the anterior slope of wave A 2.

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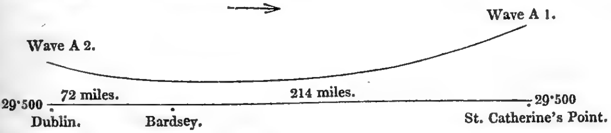
* The progression of the anterior trough of wave A 2 is clearly seen in the annexed section from Dublin to St. Catherine's Point at 9.15.



Section of anterior trough of A 2 at 9.15. The transverse section of B 1 for the same epoch cuts this line, and indicates that that wave was moving along this trough. See (20.)

† Figs. 2 and 3, Plate XLIII., have not been coloured, the *tinting* of the spaces under each curve answering the same purpose. The term "coloured" is retained in the Report as indicating that the original diagrams which accompanied it were *coloured*, and also for the purpose of more readily referring the reader to these particular diagrams.

In the explanation of Plate XLIV. the colours of the curves have been retained for the same reasons. In the original of this plate *blue* curves represent the barometer *descending*, and *red* curves the barometer *ascending*.

(22.) Nov. 9.17.0.—A maximum passes Dublin. This is most probably the apex of wave A 2.* The posterior minimum of A 1, or anterior minimum of A 2, passed this station Nov.9.1.0, and the anterior minimum of B 1 did not pass Scilly until Nov. 9.3. The rise at Dublin, South Bishop, Bardsey and Longstone must have been occasioned by the anterior slopes of A 2 and B 1 combined; but more light will be obtained on these points by a discussion of the curves of the remaining stations.

(23.) Nov. 9.18 and 19.—Scilly, South Bishop, Bardsey and Longstone nearly on a level. The barometer descending at the three first-named stations and rising at Longstone, indicates that the apex of the wave was passing between Longstone and Bardsey. The coloured diagram exhibits a considerable depth of atmosphere from St. Catherine's Point to Bardsey, and a rise from Bardsey to Dublin, showing that the trough of A 1 is still between the extreme stations, or that it has not been sufficiently *deep* to depress St. Catherine's Point below Bardsey. This, however, with several other interesting points, will be fully elucidated in the further discussion.

(24.) The characters of the two waves A 1 and B 1 (or rather three, including A 2), as developed in the foregoing inquiry, support, I apprehend, the idea of a permanent slope from Scilly to Longstone. The waves B 1 and A 2 appear to have been nearly of the same altitude, or to have exerted nearly the same pressure in their passage. The curves due to their combined action in the south of England are small: these curves increase towards the north. Longstone, which exhibits the least pressure during the period of these observations, developes the largest curve; and at this station a considerable rise is due to the passage of A 2. This must necessarily take place at a station situated as Longstone appears to be,—in a *vallée atmosphérique*†.

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* The superiority of the Dublin to the Bardsey curve, for some hours subsequent to this epoch, indicates that this maximum was due to the apex of B 1.

† Since this paragraph was written, I have inserted in Plate XLIV., fig. 1, the curves exhibiting the distribution of pressure on the line from Scilly to Longstone for the epochs Nov. 10.3 and 10.9 (see curves *g* and *h*). These curves very clearly indicate the precise characters of the waves A 1 and B 1, and when we combine them with the *synchronous* curves at these stations, we at once see that both A 1 and B 1 were small waves riding on others of a much greater magnitude. The curves *b* and *c*, fig. 1, Plate XLIV., exhibit a slope on which B 1 rolled. (See 5 and 7.) The coloured diagram at the epochs Nov. 8.21 and 9.3 also shows a very considerable fall from Scilly to Longstone. Now as Scilly exhibited the greatest and Longstone the least pressure, it is clear that these stations were situated under the *anterior* slope of the larger wave during the continuance of these conditions, provided such wave was moving in the same direction as B 1. When the apex passed between Scilly and Longstone their *synchronous* curves intersected (see fig. 2, Plate XLIII., about 18h. 30m. of Nov. 9). Immediately after the intersection Longstone became the superior curve, and upon the apex passing Longstone the previous conditions were changed, and both these stations were then situated under the *posterior* slope of the larger wave. The curves *b* and *c*, fig. 1, Plate XLIV., exhibit that portion of the slope in advance of B 1. The curve *e* of the same figure exhibits B 1 riding on the apex of this wave, and the curves *g* and *h* show its posterior slope, which succeeded B 1. By selecting two curves, *b* and *g* for instance, the change in the distribution of pressure on this line resulting from the passage of the larger wave is clearly apparent. The group of curves affords an illustration of a nodal point on a small scale,—the great extent of oscillation at Scilly, its gradual diminution towards and past Bardsey, its small amount at the point *n* between Bardsey and Longstone, and its augmentation (compared with this point) at Longstone, are interesting illustrations of the increase of oscillation noticed in Sir John Herschel's 'Report on Meteorological Reductions' (Report, 1843, p. 85), which are here clearly seen to result from the passages of the anterior and posterior slopes of a large wave *between the transits of its anterior and posterior troughs*, *n* being the nodal point in which the curves representing the anterior and posterior slopes intersect.

The following table exhibits the depression of Longstone below Scilly during a portion of the transit of the anterior slope of the larger wave, and the depression of Scilly below Longstone during the transit of its posterior slope:—

Barometric Observations reduced to the Level of the Sea, November 1842.

Epochs.	St. Catherine's.	Scilly.	South Bishop.	Bardsey.	Dublin.	Longstone.
Nov. h						
8, 15	29·901	29·849	29·810	29·627	29·563	29·470
21	·798	·702	·511	·458	·391m.	·296
9, 3	·723	·594m.	·428m.	·385m.	·395	·225m.
9	·651m.	·645M.	·529	·468	·530	·324
15	·678M.	·553	·570M.	·537M.	·576M.	·426
21	·656	·491	·477	·506	·555	·570

M maximum, m minimum.

Examination of Coloured Diagrams.

Fig. 2, Plate XLIII.—Diagram exhibiting the variations of the barometer at the stations named in the above table, the altitudes reduced to the level of the sea. The depth of each colour indicates the depression of the atmosphere between the terminating stations; and the intersections of the curves show that at the times of intersection the pressure at each station was the same, and that the relative pressure at these stations became altered, diminishing at one and augmenting at the other. The progression of the minimum in a line from Dublin to St. Catherine's Point* is very apparent, also the direction of the trough from Scilly to Longstone. The progression of the maximum from Scilly towards Longstone is also exhibited; namely, Scilly, South Bishop, St. Catherine's Point, Bardsey, Dublin. The general tendency to a level, with the intersection of the curves in the western portion of the area during the last eight hours, is very apparent.

Fig. 3, Plate XLIII.—Projection of the St. Catherine's, Bardsey and Dublin curves, showing the depth of atmosphere from St. Catherine's to Dublin, and the interchange of level between Dublin and Bardsey.

These diagrams are intended to exhibit, not only the variations of atmospheric pressure at the stations selected, but also those over the area included by them. This area is shown in fig. 1, Plate XLIII. The observations commence with a considerable dip from Scilly to Longstone; the depth of each colour indicates the *slope* between the two stations bounding it. The *form* of the atmosphere, Nov. 8.15 hours, between the two extreme stations, Scilly and Longstone, is given by the highest blue curve (a) in fig. 1, Plate XLIV. The trough of the wave A 1 (see remarks on atmospheric waves) passed Dublin about two hours earlier than the recorded minima at the other

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Epochs.		Longstone.	Scilly.	Diff. Scilly ±.
1842.				
Nov. 8,	15h	29·470	29·849	+·379
	21	·296	·702	+·406
9,	3	·225	·594	+·369
	9	·324	·645	+·321
	15	·426	·553	+·127
	21	·570	·491	−·079
10,	3	·590	·286	−·304
	9	·511	·162	−·349
	15	·286	·081	−·205
	21	·164	·061	−·103
11,	3	28·990	·081	+·091

* It is probable from other considerations that the minimum at St. Catherine's Point was occasioned by the passage of the anterior trough of wave B 1.

stations; but upon a careful consideration, the curve (Dublin) appears to indicate that the trough of this wave passed Dublin about six in the morning of the 9th Nov. About 2 P.M. Dublin and Bardsey were at the same level, the *disposition* of the atmosphere remaining the same at the other stations, and at 3 P.M. the trough of the wave A 1 extended from Scilly to Longstone. Other considerations imply that the minimum at Scilly, although coincident with the minima at South Bishop, Bardsey and Longstone, did not form a part of the posterior trough of A 1. The model of Nov. 9.9 indicates that the trough ran in a direction at right angles to a line joining Geneva and Brussels; and as a minimum passed Geneva at the same time, Nov. 9.3, it is probable that these minima, Scilly and Geneva, were occasioned by the anterior trough of B 1. At 5 P.M. Dublin attained the elevation of South Bishop, and the two curves run together until 2 A.M. of the 10th. The rise at all the stations is occasioned by the anterior slope of the wave B 1 combined with the anterior slope of A 2. The parallelism of Dublin and Bardsey is very apparent. The passages of the maximum are well-marked, Scilly occurring at 9 P.M. with the greatest elevation except St. Catherine's Point. At this moment St. Catherine's Point passes a minimum. The diagram suggests that this minimum is the posterior trough of A 1, but the model shows that the trough of A 1 is now in the neighbourhood of Bardsey, and has not yet progressed as far as St. Catherine's Point; it must therefore be the anterior trough of B 1 which occasions this depression at St. Catherine's Point. The transverse section of this wave (B 1) east of Scilly appears to be but small; it is, however, considerably enlarged towards Longstone. It appears probable that the small rise at Scilly and the smaller at St. Catherine's Point* were occasioned by a step or shoulder on the posterior slope of A 1, similar to that which appears between Bardsey and Scilly at 8.15, and in the neighbourhood of Birmingham at all the terms (see Sections and Models); and that the apex of B 1 was but slightly raised above it, so that after the passage of the step the posterior slopes of both waves coincided. South Bishop, St. Catherine's Point, Bardsey and Dublin next pass their maxima in this order. The three red curves *d e f*, fig. 1, Plate XLIV., exhibit the passage of the wave (B 1) in the direction from Scilly to Longstone. The occurrence of the maximum at St. Catherine's Point and Bardsey about the same time indicates the direction of the crest of B 1 to pass through these stations: this direction is rather different from the direction of the anterior trough, for Geneva does not pass its maximum until 9.21. At 2 A.M. of the 10th a decided change of level takes place in three localities, Scilly, Dublin and South Bishop: this is evidently occasioned by the passage of the posterior slope of B 1 over Scilly at the time the apex is approaching South Bishop and Dublin. At 3 A.M. the apex passes South Bishop, and shortly after Scilly and Bardsey are on the same level with South Bishop rising between them. The next intersections of the curves occur betwen 6 and 7 A.M. of the 10th; the highest level is Bardsey and South Bishop, and the lowest Longstone and Scilly. The apex is now rapidly rolling on towards Longstone, depressing South Bishop. Shortly before 7 Longstone and Bardsey are on the same level, the wave rising between them. About 8 the curves of Scilly and South Bishop again intersect, and immediately after Longstone and Dublin are at the same level.

General Conclusion.

That while the posterior slope of a very large wave, with a shoulder producing a small trough (A 1), passed over the area, a small wave passed over at a considerable angle to the first. The passage of the apex of this wave

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* The maximum occurring earlier at St. Catherine's Point than at Dublin, clearly indicates that the St. Catherine's maximum was due only to the apex of B 1.

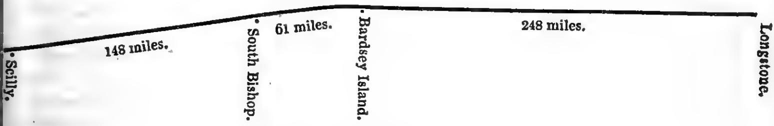
(B 1) has been most satisfactorily traced, but the distance from Scilly to Longstone was not long enough to exhibit the span and altitude*.

Explanation of the Sections of Waves, Figs. 1, 2 and 3, Plate XLIV.

Fig. 1.—The curves in this figure are intended to exhibit the variations of pressure from Scilly to Longstone; the extent and form of the line selected is shown below. The three blue curves, *a b c*, give the approximate atmospheric *form*, the barometer descending. The three red curves, *d e f*, the variations of *form* during the passage of wave B 1, and the curves *g h* the form of the posterior slope of the larger wave on which B 1 was superposed. See note to (24.), Remarks on Atmospheric Waves.

Fig. 2.—The curves in this figure represent the form of the atmosphere between Geneva and Brussels. They are projected from the reduced altitudes at Geneva and Brussels, and altitudes taken from the models at two points, 01 and 02; 01 between Geneva and Brussels, and 02 in the same line beyond Brussels.

Fig. 3.—The curves in this figure represent the *form* of the atmosphere in a line from Brussels by Birmingham to Dublin, with two intermediate stations, as in fig. 2.



Additional Remarks.

(1.) The object of the discussion of the barometric observations of the 9th and 10th of November 1842, has been to obtain, as nearly as possible, a clear apprehension of the distribution of atmospheric pressure with its variations over the area included by the stations furnishing observations, previous to undertaking an examination of the great symmetrical wave which traversed Europe from the 11th to the 25th of the month. In the course of the examination, the sections for the epoch November 9.3 are the most complete; and as but few of them have been given, it may be interesting to subjoin the results obtained from an examination of the remaining sections, especially as they are particularly illustrative of the wave A 1, which has already been alluded to as traversing Europe on those days.

Epoch, Nov. 9.3.0, 1842; area, Longstone, Dublin, Scilly, Paris, Heligoland, Munich, Geneva.

(2.) In this area, Longstone, Scilly and Brussels form a triangle inclosing England. Longstone to Brussels will give a section of the distribution of pressure on the eastern coasts of England; Longstone to Scilly, the distribution on the western, and Scilly to Brussels on the southern; Longstone, Birmingham and St. Catherine's Point, the distribution nearly from north to south†.

(3.) An inspection of these sections, as given in the first sheet of sections, Plate XLV., will show that the most precipitous slope occurred on the eastern shores of our island, and that this is characterized by a bulge (or most probably a superposed wave) in the neighbourhood of Haisboro on a normal wave or a permanent slope. The same result is obtained across the island from observations entirely distinct, as at Birmingham and St. Catherine's Point, and the two sections are essentially similar, especially in the precipitous manner in

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* A more attentive consideration of the circumstances of the passages of these waves has induced me to come to the conclusion, that the span of B 1 was 341 miles and its altitude ·090 inch. See (20.), Remarks on Atmospheric Waves.

† The coast line of England has been inserted in Plate XLII., in order to illustrate the sections in Plate XLV.

which the line 29·500 is crossed. They appear in fact to be *converging* sections of a wave having its posterior trough near and to the north of Longstone.

(4.) The western section from Scilly to Longstone presents a nearly unbroken descent, and it is probable that the wave which is so apparent on the central and eastern sections did not extend to this; there is a slight rise a little to the north-east of Bardsey, which may probably result from the extremity of the wave. The section from Brussels to Scilly is also of an unbroken character.

(5.) The central and southern sections are crossed by two others, which exhibit the distribution of pressure over the area included by Dublin, Munich and Geneva; these sections (Plate XLVI.) are extremely interesting, they supply deficiencies in the sections already given, and are both characterized by two bulges or superposed waves. The lowest of these waves (A 1) stretches from the coast of Wales to the coast of Holland on the Munich line; and from Bardsey to the coast of France on the Geneva line. From a careful consideration of the sections drawn in other directions, there can be no question that the bulge on the eastern and central of the English sections and this wave is the same. It covered nearly the whole of England at this time (Nov. 9.3.0), its apex or crest stretched from Cornwall to the shores of Suffolk, taking a somewhat circular direction about midway between London and Birmingham, and it is probable that it extended considerably towards the east over the German Ocean, and on the continent.

(6.) Of the wave preceding this we obtain but a small portion; the two sections from Dublin to Munich and Geneva indicate that the direction of the crest was nearly parallel to that of the wave we have just examined. A section exhibiting the distribution of pressure from Longstone to Geneva, constructed from interpolated ordinates, also gives this wave.

(7.) The curves exhibiting the distribution of pressure are constructed from observed and *interpolated* ordinates. The latter are measured on those points of the curves where they intersect others, and where the pressure must necessarily be the same in both. The sections are consequently mere approximations to those that would be given were the stations of observation sufficiently near to each other to project from them the true curves of pressure on a line, as from Dublin to Munich; in fact we require a much longer line than this, which probably does not give the half breadth of the normal wave. The same principle of short intervals, which Sir John Herschel has so efficiently applied to time in the solstitial and equinoctial observations, applied to space in arranging series of observations on certain lines, would make us acquainted with the true distribution of pressure over a tract of country, and the two combined would give us the march as well as the distribution.

(8.) The waves deduced from the observations are affected by two circumstances, namely, the diurnal oscillation, which must to a certain extent interfere with the *form* of the wave, and the influence of the aqueous vapour diffused in the atmosphere. The pressure of the aqueous vapour varies in a different manner to that of the gaseous atmosphere, and will materially modify the forms of the waves, &c. On the occasion we have been examining the pressure of the vapour increases, while that of the *whole* atmosphere decreases. It appears quite as important to examine the distribution of the vapour over a tract of country as that of the whole pressure; and in pursuing the investigation, it is necessary either to get rid of the effects of the vapour, or to examine how far it influences the forms, directions, amplitudes and progress of the waves deduced from the whole pressure. In order to render barometric observations as efficient as possible, it will be absolutely necessary to observe at the same time the wet and dry bulb thermometer, and it would be still better to accompany them with readings of Daniell's hygrometer. The determination of the co-efficients of the diurnal oscillation will also become of paramount importance, that the forms of the waves may be corrected.

Rapport sur les Poissons Fossiles de l'Argile de Londres.
Par L. AGASSIZ.

LES fossiles de l'argile de Londres ont attiré depuis longtemps l'attention des géologues par le nombre considérable et la variété de leurs espèces qui appartiennent à toutes les classes du règne animal et végétal, ainsi que par le bel état de conservation dans lequel se trouve un grand nombre d'entre eux. Depuis les Recherches de Sowerby sur les coquilles de ce terrain, nous avons vu paraître plusieurs mémoires d'un mérite éminent sur les fossiles de différentes classes. Mr. Owen a décrit avec sa supériorité habituelle les reptiles, les oiseaux et les mammifères qu'on trouve épars ça et là dans les couches de ce terrain, et ses savantes investigations ont jeté un jour tout nouveau sur les rapports qui lient les êtres fossiles de cette formation aux espèces de la création actuelle. Tout le monde connait le beau travail de Mr. Bowerbank sur les fruits de ce même terrain. L'ichthyologie seule avait été à peu près complètement négligée. Ce n'est pas qu'il y ait pénurie de poissons fossiles dans ce dépôt; car il n'est pas de gîte à poisson connu qui en compte autant d'espèces, et aucune collection de fossiles tertiaires d'Angleterre qui n'en renferme au moins quelques exemplaires. L'ignorance dans laquelle nous avons été jusqu'ici à l' égard des poissons de Sheppy n'a d'autre cause que les difficultés toutes particulières qu' offre l'étude de leurs débris. Ailleurs, et notamment dans les couches des terrains primaires et secondaires, dans les schistes, les calcaires, les grès, les ichthyolithes sont plus ou moins entiers, et il est rare qu'un fragment n'offre plusieurs parties du corps, différentes parties des nageoires, de la cuirasse écailleuse, de l'appareil operculaire, &c.; ou bien si les pièces elles-mêmes ne sont pas conservées, leur empreinte indique au moins la forme générale et les contours du corps, ensorte qu' avec une connaissance

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Report on the Fossil Fishes of the London Clay. *By* L. AGASSIZ.

THE fossils of the London clay have long since attracted the attention of geologists, from the considerable number and variety of their species belonging to all classes of the animal and vegetable kingdom, as well as from the beautiful state of preservation in which a large number of them occur. Since the researches of Sowerby on the shells of this deposit several memoirs of great merit have appeared on the fossils of different classes. Professor Owen has described with his usual acuteness the reptiles, birds and Mammalia which are met with scattered here and there in the layers of this deposit, and his erudite investigations have thrown quite a new light on the relations which connect the fossil creatures of this formation with the species of the present epoch. The beautiful work of Mr. Bowerbank on the fruits of this deposit is well known to every one. The Ichthyology alone had been almost entirely neglected; not that there is any scarcity of fossil fish, for there is no known fish-bed which counts so many species, and no collection of tertiary fossils of England which does not at least contain some specimens. The want of knowledge which has hitherto prevailed with respect to the fish of Sheppey is solely owing to the very peculiar difficulties which the study of their fragments present. Elsewhere, and especially in the strata of primary and secondary rocks, in the schists, limestones and sandstones, the ichthyolites are more or less entire; and it is seldom that a fragment does not present several parts of the body, different portions of the fins, of the scaly coating, of the opercular apparatus; or, if indeed the pieces themselves are not preserved, their impression indicates at least the general form and the outlines of the body; so that with a sufficient knowledge of living fish, of suffisante des poissons vivans, de leur forme et de leurs caractères extérieurs, on peut arriver à des déterminations exactes et rigoureuses. En outre la plupart des poissons anciens ont des écailles osseuses plus dures même que les os et leur enchevètrement contribue à conserver la forme générale du poisson, quand même les os ont disparu et que les autres parties sont détruites.

Ce sont ces caractères extérieurs, entre autres la forme, le nombre et la position des nageoires, la structure des écailles, les rapports des différentes parties du corps entre elles, la dentition, l'arrangement des pièces operculaires, &c., sur lesquels on a basé jusqu'à présent les classifications en ichthyologie. Que l'on parcoure les ouvrages les plus estimés de notre temps sur l'histoire naturelle des poissons, on ne rencontrera dans les diagnoses des familles, des genres et des espèces, que des caractères extérieurs, faciles à saisir et suffisants aussi pour le but qu' on se propose. Si je parle de lacunes, que présente encore cette branche de la science, à laquelle je me suis voué depuis tant d'années, ce n'est pas que je veuille amoindrir le moins du monde le mérite de tant d'ouvrages que la postérité la plus reculée regardera encore comme des chefs d'œuvres de sagacité, d'application et d'étude; mais c'est qu'ayant choisi une branche toute spéciale de l'ichthyologie, j'ai peut être été plus à même qu'un autre, d'entrevoir tout ce qu'il reste à faire dans ce vaste domaine. Cela est surtout vrai à l'égard des poissons de Sheppy, qui n'ont plus rien de ces formes et de ces caractères bizarres propres à la plupart des poissons des anciennes formations. Tout en eux rappelle au contraire les poissons de nos mers actuelles, en sorte qu'avant d'en avoir fait une étude détaillée, on croirait avoir à faire à des espèces récentes. Leurs débris sont enfouis dans un limon plus ou moins durci, qui quelquefois prend la dureté des roches calcaires, tandis qu'en d'autres endroits il est resté parfaitement mou. La

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their form and external characters, it is possible to arrive at accurate and strict determinations. Moreover, the majority of older fish have osseous scales harder even than the bones; and the mode of their arrangement (*enchevètrement*) contributes to preserve the general form of the fish even when the bones have disappeared and the other parts have become destroyed.

Classifications in ichthyology have hitherto been based on external characters; among others, on the form, number and position of the fins, the structure of the scales, the relations of the different parts of the body to each other, the dentition, the arrangement of the opercular pieces, &c. If we glance over the most esteemed works of our time on the natural history of fish, none but external characters will be met with in the diagnoses of the families, genera and species, easily conceived, and sufficient indeed for the proposed object. If I speak of the voids which this branch of science, to which I have devoted myself for so many years, presents, it is not that I wish to detract the least in the world from the merit of so many works which the most distant posterity will still regard as master-works of sagacity, application and research; but it is that having selected a special branch of ichthyology, I have perhaps been enabled more than others to perceive what remains to be done in this vast domain. This is especially true with respect to the Sheppey fish, which have none of those forms and of those fantastic characters peculiar to the majority of the fish of the older formations; all in them, on the contrary, recall to mind the fish of our present oceans, so that before having made a minute study of them, we should be inclined to think that we had to do with recent species. Their fragments are buried in a more or less hardened clay, which sometimes presents the hardness of calcareous rocks, while in other localities it has remained per-plupart des poissons se sont pourris dans ce fin limon, leurs os se sont détachés, et les parties molles ont été remplacées par du limon. Or comme ce ne sont plus des Ganoïdes à corps cuirassée recouverts d'écailles osseuses enchevètrés, mais des Cycloïdes, des Cténoïdes à écailles minces, fragiles, leur enveloppe n'a pas été assez solide pour maintenir l'intégrité de leur forme et de leurs contours. Leur corps s'est décomposé, leurs nageoires se sont défaites, leurs écailles désagrégées, et il n'est resté du plus grand nombre que les boîtes crâniennes qui se sont conservées en entier, grâce à la soudure de leurs pièces osseuses. Si au lieu d'appartenir à des poissons, ces crânes provenaient de mammifères ou de reptiles, il est à présumer qu'on en tirerait tout le parti possible, et que le paléontologiste n'aurait pas de peine à les déterminer, car pour ces classes les matériaux de comparaison ne manquent pas, les points de départ sont fixés; on connaît les traits caractéristiques des crânes des mammifères et des reptiles, on sait quelles sont les variations que tel os, telle crête, telle fosse part subir dans telle ou telle famille, et du premier coup d'œil déjà on peut s'assurer, si l'animal qu'on a devant les yeux, est un carnivore, un ruminant, ou un solipède.

Mais rien n'est variable comme les formes du crâne et de la tête des poissons. Ces multitudes d'arêtes et d'épines qui servent d'attache aux muscles, cette infinie variété de formes dans les familles elles-mêmes, donne aux crânes des poissons une telle diversité que l'ichthyologiste désespère souvent de pouvoir les ramener à leurs types respectifs, et en effet une craniologie comparée des poissons n'existe pas, et il n'est personne que je sache qui puisse dire d'emblée si tel ou tel crâne appartient à un Percoïde, à un Sparoïde, ou à un Chétodonte, &c.

La grande majorité des fossiles de Sheppy avons nous dit, consiste en ver-

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fectly soft. The greater number of the fish have rotted in this fine clay, their bones have separated, and the soft parts have been replaced by clay. Now, since it is no longer Ganoids with cuirassed body covered with interlocked bony scales, but Cycloids and Ctenoids with thin fragile scales, their coating has not been sufficiently solid to preserve the integrity of their form and outline. Their body has become decomposed, their fins have become detached, their scales disaggregated, and of the greater number only the cranium has remained preserved entire, owing to the soldering of the osseous pieces composing it. If, instead of belonging to fish, these skulls were derived from Mammalia or reptiles, it is to be presumed that all possible advantage would be taken of them, and that the palæontologist would have no trouble in determining their relations, since for these classes the materials for comparison are not wanting, the points of departure are fixed. The characteristic features of the skulls of the Mammalia and Reptilia are known; the variations which such a bone, such a crest, such a groove may undergo in such and such a family are understood, and already at the first glance it is possible to ascertain whether the animal under consideration is carnivorous, ruminant, or solipedal.

But nothing is more variable than the forms of the cranium and of the heads of fish. The multitude of bones and of spines which serve for the attachment of the muscles, the infinite variety of forms in the families themselves, imparts such a diversity to the crania of fish, that the ichthyologist frequently despairs of being able to reduce them to their respective types, and in fact a comparative craniology of fish does not exist. There is no one that I know who can tell at first sight whether such and such a cranium belongs to a Percoid, to a Sparoid, or to a Chetodontal type.

The great majority of the fossils of Sheppey consists, we have said, of detèbres détachées ou en crânes isolés. Ces derniers sont en outre ordinairement dépourvus des os de la face; les mâchoires, les appareils operculaires et branchiaux manquent, et il n'est resté le plus souvent que la boîte cranienne proprement dite, et très-souvent même il lui manque toute la partie antérieure, le museau, formé par la réunion des naseaux et du vomer, de sorte qu'on n'a d'autre point de départ que la boîte cérébrale dégagée de tous ses appendices. Pour déterminer ces débris, j'ai suivi le même procédé que la nature a employé pour mettre ces fossiles dans l'état dans lequel nous les trouvons. Des squelettes ordinaires, tels qu'on les a dans les musées d'histoire naturelle et d'anatomie comparée, n'auraient pu suffire à mon but. J'ai donc commencé par préparer un certain nombre d'ossemens détachés de différens poissons marins, et je possède maintenant une centaine de crânes isolés, avec les autres os détachés, collection que j'augmente journellement. Comme il importe que les différens os du crâne ne soient pas isolés, mais que la boîte crânienne conserve sa forme naturelle, tous ces crânes ont dû être préparés avec le plus grand soin; et ici s'est présenté une grande difficulté, qui résulte de la manière dont les os du crâne sont joints chez les poissons. Chez les autres vertébrés cette jonction se fait par sutures, les bords crenelés et dentelés se correspondent, et il est facile de reconstruire un crâne démembré. Chez les poissons il n'en est point ainsi. Le plus souvent les os sont appliqués sur une boîte cartilagineuse interne, souvent très épaisse, d'autres fois plus mince, et leurs bords, si toutefois ils se touchent, sont appliqués les uns sur les autres par leurs faces, ou bien séparés par de larges bandes de cartilage. La forme générale du crâne est donc souvent tout à fait différente de ce qu'elle serait si l'on essayait de reconstruire le crâne avec des ossemens isolés, en rapprochant ces derniers par leurs bords. Dans les poissons de Sheppy les cartilages ont

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tached vertebræ, or of isolated crania. The latter, moreover, are generally deprived of the bones of the face; the jaws, the opercular and branchial apparatus are wanting, and most frequently only the cranial envelope, properly so called, remains; and very often indeed even this has lost the whole of the anterior portion, the snout formed by the union of the nostrils and of the vomer, so that there is no other point to start from than the cranium, deprived of all its appendages. To determine these fragments, I have followed the same process that nature employed to place these fossils in the state in which we meet them. Ordinary skeletons, such as are contained in the museums of natural history and comparative anatomy, would not have sufficed for my purpose. I began therefore by preparing a certain number of detached bones of different marine fish, and I possess at present a hundred detached crania with the other bones separated, a collection which I am daily increasing. As it is of importance that the different bones of the cranium be not isolated, but that the envelope which they form should preserve its natural form, all these crania have required the greatest care in their preparation; and in this a great difficulty occurred, arising from the manner in which the bones of the cranium are joined in fish. In the other Vertebrata this junction is effected by sutures; the crenulate and dentate margins correspond, and it is easy to reconstruct a dismembered cranium. In fishes such is not the case. Most frequently the bones are applied on to an internal cartilage form, frequently very thick, sometimes thinner, and their margins, if indeed they touch, are applied the one on the other by their faces, or separated by broad bands of cartilage. The general form of the cranium is therefore frequently entirely different from what it would be if we were to attempt to reconstruct the cranium with isolated bones, approximating these latter by their margins. In the fish from Sheppey the cartilages have disappeared, the clay has taken disparu, le limon les a remplacés, mais pas entièrement, de manière que les crânes ont la forme que prennent des crânes à demi-sechés de poissons vivants. C'est ce point de désiccation que j'ai cherché à atteindre dans mes crânes de poissons vivants.

Ces moyens de comparaison pourraient paraître suffisants, si l'on ne rencontrait une autre difficulté, qui s'oppose à l'application directe de ces matériaux au but que l'on se propose. Les poissons de Sheppy appartiennent aux dépôts tertiaires ; ils se rapprochent par conséquent des types qui vivent maintenant. Mais on sait, et l'étude des poissons de Monte-Bolca l'a suffisamment prouvé que, plus les familles et les genres remontent à des terrains anciens, moins ils comptent de représentans dans la création actuelle, et encore ces représentans se trouvent ils en général dans des parages très éloignés. Ainsi, de toute la puissante famille de Sauroïdes qui anciennement peuplait les mers, il n'est resté que deux représentans dans les eaux douces de la création actuelle, tandis que les familles les plus nombreuses de notre époque, les Siluroïdes, les Cyprins, les Gades, et plusieurs autres ne comptent que peu ou point de représentans parmi les fossiles. Ce n'est donc pas parmi les poissons les plus communs de nos côtes, qu'il faut chercher les analogues des poissons fossiles tertiaires. En passant en revue les ichthyolithes de Monte Bolca, on rencontre une quantité de poissons, faisant partie de familles peu nombreuses dans nos parages, dont les représentans ne vivent pour la plupart que dans les mers des Indes ou de l'Ocean austral, tels que les Squammipennes, les Aulostomes, les Gymnodontes, les Sclérodermes, &c. &c.

Pour déterminer rigoureusement les poissons de Monte Bolca ou des autres dépôts tertiaires j'ai pu appeler à mon secours les matériaux rassemblés dans les musées, et surtout les squelettes du musée de Paris. Les comparaisons devaient surtout porter sur le corps, les nageoires, tous points qui sont assez

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their place, but not entirely, so that the crania have the form which the skulls of half-dried recent fish acquire. It is this point of desiccation which I have endeavoured to attain in my crania of recent fish.

These means of comparison might appear sufficient, did we not meet with another difficulty which is opposed to the direct application of these materials to the object in view.. The fish of Sheppey belong to the tertiary deposits, they consequently approach types at present existing. But it is known, and the investigation of the fish of Monte Bolca has sufficiently proved, that the more the families and genera ascend to the older deposits, the less number of representatives do they possess in the present creation, and these representatives are moreover in general met with in distant regions. Thus of all the large family of the Sauroids which formerly peopled the sea, but two representatives remain in the freshwaters of the present creation, while the most numerous families of our epoch, the *Siluri*, the *Cyprini*, the *Gadi*, and several others, have few or no representatives among fossils. It is therefore not among the most common fish of our coasts that we must search for the analogues of the fossil tertiary fish. On passing in review the ichthyolites of Monte Bolca, we meet with a quantity of fish belonging to families containing few members in our seas, the representatives of which live for the greater part only in the Indian sea, or the southern ocean, such as the *Squamipennæ*, the *Aulostomaia*, the *Gymnodonts*, the *Sclerodermata*.

To determine accurately the fish of Monte Bolca, or of the other tertiary deposits, I have been able to call to my aid the materials collected in the Museums, and especially the skeletons in the Museum of Paris. The comparisons had principally to be made with the body and the fins, which are bien conservés dans ces fossiles et que les squelettes mettent en évidence. Pour déterminer les poissons de Sheppy je devrais avoir à ma disposition une collection non moins riche de squelettes démembrés, de crânes détachés, d'ossemens isolés. Or, une telle collection ne peut se faire que lentement et à grands frais, surtout lorsque celui qui la forme vit éloigné de la mer et n'a à sa disposition qu'un petit musée destiné plutôt à acquérir des exemplaires typiques de genres, que des séries d'exemplaires de la même espèce.

Si malgré ces difficultés je puis présenter aujourd'hui un aperçu assez complet sur les poissons fossiles de Sheppy, je le dois à l'obligeance des géologues anglais, en particulier de Lord Enniskillen, de Sir Ph. Egerton, du Dr. Buckland, du Rev. M. Hope, de MM. Bowerbank, Cumberland, des Directeurs du Musée Britannique, du Collège des Chirurgiens, &c., qui tous m'ont communiqué à l'envi les pièces originales de leurs collections, que j'ai pu de cette manière comparer directement avec des crânes de poissons vivans. Ce travail a ainsi été fait sur des bases toutes neuves. Les travaux des ichthyologistes antérieurs n'ont pu même m'être que d'un faible secours, et même les grands ouvrages d'anatomie comparée de Cuvier, de Meckel, et de tant d'autres m'ont rarement fourni des renseignemens suffisants, car ils ont pour but de faire connaître les os du crâne et de la tête en général, d'indiquer la part que ces os prennent à la formation du squelette osseux de la tête, de décrire les variations qu'ils peuvent subir en composant les types les plus extravagants, et enfin de faire ressortir l'analogie des os avec ceux des autres classes des vertébrés plutôt que d'indiquer la forme précise de chaque os dans tous les genres. Il en est de même des grandes discussions anatomiques du commencement de notre siècle qui ont porté sur l'analogie de la

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tolerably well-preserved in those fossils, and which are exhibited by the skeleton. To determine the fish of Sheppey, I was obliged to have at my disposal a collection not less rich of dismembered skeletons, detached crania, and of isolated bones; but it is only possible to form such a collection slowly and at great expense, especially when the person who forms it lives at a distance from the sea, and has at his disposal but a small museum, destined rather to receive typical specimens of genera than series of specimens of the same species.

If, notwithstanding these difficulties, I am able to offer at present a tolerably complete sketch of the fossil fish of Sheppey, I owe it to the kindness of English geologists, in particular of Lord Enniskillen, of Sir Philip Egerton, of Dr. Buckland, of the Rev. Mr. Hope, of Messrs. Bowerbank, Cumberland, the Directors of the British Museum, of the College of Surgeons, &c., who have all eagerly communicated to me the original fragments from their collections, which I have thus been able to compare directly with the crania of recent fish. This investigation has thus been made on entirely new bases. The labours of former ichthyologists have scarcely afforded the least assistance; and even the great works on Comparative Anatomy of Cuvier, Meckel and so many others have rarely furnished sufficient information; for their object is to make known the bones of the cranium and of the head in general, to indicate the part which these bones take in the formation of the osseous skeleton of the head, to describe the variations they may undergo in composing the most extravagant types, and lastly, to point out the analogy of the bones with those of other classes of Vertebrata, rather than to indicate the precise form of each bone in all the genera. The same is the case with respect to the great anatomical discussions at the commencement of the present century, which related to the analogy of the head of fish with that of the other tête des poissons avec les autres vertébrés plutôt que sur les détails nécessaires à la détermination des os fossiles.

Le but que j'ai dû me proposer dans ces nouvelles études sur l'ostéologie des poissons est avant tout de connaître les formes de la tête et du crâne, d'en déterminer les arêtes, les fosses, le relief dans tous leurs détails, et de retrouver dans ces différentes formes des types généraux de la famille, du genre, de l'espèce. Si mes prédécesseurs se sont attachés à un type régulier, la carpe ou la perche, en décrivant leur ostéologie, et en indiquant combien ces types peuvent varier dans les genres irréguliers, j'ai dû au contraire m'attacher principalement aux types peu differenciés, rechercher les petites déviations, qui peuvent accompagner les différences spécifiques, étudier le caractère général du genre, indiquer les variations que peut subir le type encore plus général de la famille, et arriver ainsi à pouvoir distinguer les familles, les genres, les espèces d'après l'ostéologie du crâne. Cette étude, on le sent bien, est presque sans fin; car,—et c'est là une nouvelle manifestation de l'infinie variété de la nature—chaque genre, chaque famille a ses traits caractéristiques, et ses variations spécifiques ont lieu dans des limites déterminées. Chez telle famille l'absence d'une crête mitoyenne du crâne, peut-être un trait caractéristique, commun à toute la famille, tandisque chez telle autre cette crête ne formera qu'un caractère de genre ou d'espèce, et ainsi de suite. Pour arriver à la connaissance exacte et détaillée des lois qui président à toutes les variations qui peuvent survenir dans les espèces, les genres, les familles, il faudrait posséder les crânes de toutes les espèces de poissons connus jusqu'à présent. Espérons qu'on y arrivera quelque jour. Pour le moment nous en sommes encore fort loin.

Pour donner un aperçu de la manière dont il faut traiter l'ostéologie des

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Vertebrata, rather than to the details necessary for the determination of fossil bones.

The object which I proposed to attain in these new researches on the osteology of fish, was above all to become acquainted with the forms of the head and of the cranium, to determine their ridges, the hollows, and the relief in all their details, and to find in these different forms general types of the family, of the genus, and of the species. If my predecessors have fixed on a regular type, the Carp or Perch, in describing their osteology, and in pointing out how these types may vary in the irregular genera, I on the contrary have had to direct my attention principally to closely-allied types, to search for the minute deviations which might accompany specific differences, to study the general character of the genus, to indicate the variations which the still more general type of the family might be subject to, and thus to arrive at the possibility of distinguishing families, genera and species by the osteology of the cranium. It will be conceived that this study is almost interminable; for,—and this is a new manifestation of the infinite variety of nature—each genus, each family has its characteristic features, and its specific variations occur within fixed limits. In one family the absence of a central crest of the cranium may constitute a characteristic feature common to the whole family, while in another this crest will form but a generic or specific character, and so on. To arrive at an exact and minute knowledge of the laws which determine all the variations that may occur in the species, genera and families, it will be necessary to possess the crania of all fish hitherto known. Let us hope that some day we shall arrive at this point; at present we are still far distant from it.

To give a sketch of the manner in which the osteology of fish must be poissons, dans le but d'éclairer l'étude des poissons fossiles et de ceux de Sheppy en particulier, je vais indiquer en peu de mots les traits caractéristiques des principales familles dont on a rencontré jusqu'ici des représentans dans l'argile de Londres. Si je ne dis rien des autres familles, ce n'est pas que je les aie négligées, mais ne voulant pas allonger ce rapport, je m'en tiendrai exclusivement à celles qui ont des représentans parmi les fossiles de Sheppy.

La famille des *Percoïdes* se distingue par le développement considérable de l'occiput, tandis que les parties antérieures du crâne sont très-étroites et peu développées. La crête mitoyenne du crâne ne s'élève presque jamais au dessus du plan incliné du front. Les frontaux eux-mêmes ne présentent jamais de crète bien marquée et dans aucun cas la crète mitoyenne ne se continue sur les frontaux. Il y a même toujours une partie plus ou moins considérable de l'occipital supérieur qui s'intercale entre les petits parietaux et l'extrémité des frontaux, et qui est aplatie comme le front. Les crêtes pariétales ou intermédiaires sont toujours bien prononcées et aplaties à leur extrémité postérieure. Les crètes temporales sont fortes et séparées des précédentes par une fosse temporale profonde, au fond de laquelle on aperçoit une lacune plus ou moins grande entre l'occipital externe et le temporal. Cette lacune est bouchée par du cartilage. Jamais aucune de ces fosses ne s'avance au delà du bord postérieur de l'orbite, ou, en d'autres termes, jamais les fosses temporale et occipitale ne se continuent sur les frontaux principaux. La partie inférieure du crâne n'offre presque jamais de traits caractéristiques. J'ai trouvé jusqu'ici parmi les poissons de Sheppy sept genres de Percoïdes, dont l'un le *Cœloperca*, se rapproche beaucoup du genre Perca proprement dit, tandis que les 4 autres, *Podocephalus*, *Brachygnathus*, *Percostoma* et *Synophrys* ressem-

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treated for the purpose of throwing light on the investigation of fossil fish, and in particular on those of Sheppey, I shall indicate in a few words the characteristic features of the principal families, representatives of which have been met with in the London clay. If I pass over in silence the other families, it is not that I have neglected them; but not wishing to extend this report to too great a length, I shall confine myself exclusively to those which have representatives among the fossils of Sheppey.

The family of the *Percoidæ* is distinguished by the considerable development of the occiput, while the anterior portions of the cranium are very narrow and only little developed; the central crest of the cranium rarely rises above the inclined plane of the front. The frontals themselves never present a very marked crest, and in no case does the central crest continue on the frontals. There is indeed always a more or less considerable portion of the upper occipital which is inserted between the small parietals and the extremity of the frontals, and which is flattened like the front. The parietal or intermediary crests are always very marked and flattened at their posterior extremity. The temporal crests are strong and separated from the preceding by a deep temporal groove, at the bottom of which is perceived a more or less large space between the external occipital and the temporal. This space is filled up by cartilage. Never do any of these grooves advance beyond the posterior margin of the orbit, or in other words, the temporal and occipital grooves never continue over the principal frontals. The lower portion of the cranium scarcely ever presents characteristic features. I have found up to the present time among the fish of Sheppey seven genera of *Percoidæ*, one of which, *Cœloperca*, approaches considerably to the genus *Perca* itself, whilst the four others, *Podocephalus*, *Brachygnathus*, *Percostoma* blent d'avantage aux Serrans, et le genre *Eurygnathus* aux Centropomes. Le septième genre est le seul qui existe aussi dans la création actuelle, c'est un veritable *Myripristis*, appartenant à ce curieux groupe de Percoïdes à plus de sept rayons à la membrane branchiostègue et aux ventrales, et qui probablement devra former à l'avenir une famille à part, à cause de la structure tout à fait différente de ses écailles et de sa vessie natatoire.

Je n'ai pas encore pu trouver des restes de *Sciénoïdes*. On sait que la tête de ces poissons se reconnaît facilement à ses boursoufflures caverneuses, qui sont dûes à un développement énorme des canaux mucifères de la tête. Les *Joues cuirassées* ne figurent pas non plus dans les couches de Sheppy.

La famille des *Sparoïdes* compte plusieurs représentans dans l'argile de Londres. Ce qui distingue cette famille c'est la forme de la crète occipitale qui s'avance jusqu'au milieu de l'orbite, mais ne la dépasse jamais. Dans les Sparoïdes ordinaires, tels que les Dentés, les Spares, les Pagres, la face supérieure du crâne forme une ligne brisée sur deux points, en sorte que le nasal et le vomer avec la crète supérieure tranchante représentent un plan incliné, tandis que la partie moyenne des frontaux est presque horizontale, et l'occiput descend de nouveau en arrière. Les crètes intermédiaires sont assez hautes, mais très minces et tranchantes comme la crète occipitale ; elles s'avancent au delà du bord supérieur de l'orbite et forment en général un angle aigu, dont la pointe se réunit au milieu du front avec la crète occipitale mitoyenne. Les crètes temporales sont en général plus épaisses, et offrent de nombreuses ouvertures pour les canaux mucifères, d'où résulte parfois une assez grande ressemblance avec des Sciénoïdes. La crète temporale est séparée du bord postérieur de l'orbite par une fosse assez profonde qui conflue avec la fosse mastoïdienne. J'ai pu m'assurer au moyen de ces caractères que le genre

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and *Synophrys*, more resemble the *Serrani*, and the genus *Eurygnathus* the *Centropomi*. The seventh genus is the only one which exists in the present creation ; it is a true *Myripristis* belonging to that curious group of *Percoidæ* which has more than seven rays to the branchiostegous membrane and to the ventrals, and which will probably form in future a separate family, on account of the entirely different structure of the scales and of the swimming-bladder.

Hitherto I have not met with remains of *Sciænoidæ*. The head of these fish is easily recognised by the hollow protuberances arising from an enormous development of the muciferous canals of the head. Neither do the '*Joues cuirassées*' (*Cottoïdæ*) occur in the Sheppey strata.

The family of the *Sparoidæ* has several representatives in the London clay. What distinguishes this family is the form of the occipital ridge, which advances to the middle of the orbit, but never extends beyond it. In the ordinary *Sparoidæ*, such as the *Dentices*, the *Spari* and the *Pagri*, the upper surface of the cranium forms a line interrupted at the two points, so that the nasal and the vomer with the sharp-edged upper crest represent an inclined plane, while the central portion of the frontals is nearly horizontal, and the occiput again descends posteriorly. The intermediary crests are tolerably high, but very thin and sharp-edged, like the occipital crest ; they advance beyond the upper margin of the orbit and form in general an acute angle, the apex of which unites at the middle of the front with the median occipital crest. The temporal crests are in general thicker and present numerous apertures for the muciferous canals, whence sometimes results a great resemblance with the *Sciænoidæ*. The temporal crest is separated from the posterior margin of the orbit by a tolerably deep groove, which is confluent with the mastoid groove. I have been able to convince myself by means of these

Sciænurus, que j'avais placé provisoirement parmi les Sciénoïdes appartient effectivement aux Sparoïdes, et doit être placé dans le voisinage des Dentés.

La famille des *Teuthies* est caractérisée par une séparation assez tranchée entre l'occiput et la partie antérieure de la tête comprenant les frontaux et les autres os contigus. Les formes générales de la tête varient beaucoup; cependant il y a toujours une petite crète occipitale assez mince et fragile, ainsi que des crètes pariétales et temporales. Les intervalles qui séparent ces crètes ne sont pas de véritables fosses, ou du moins elles ne sont pas plus profondes que la surface du crâne en général, et les crètes ressemblent plutôt à de petites lames tranchantes posées sur cette surface uniformément bombée. Les frontaux sont en général grands et vigoureux; ils sont plus épais que dans aucune autre famille, et montrent des dessins variés dans l'arrangement de leurs fibres osseuses. Le plus souvent ils présentent de fines mailles ou des pores très-serrés. La surface inférieure du crâne forme une quille tranchante tout le long du sphénoïde.

Je connais jusqu'ici trois genres appartenant à cette famille, qui se trouvent dans l'argile de Londres. L'un, le *Ptychocephalus radiatus* se rapproche assez des Amphacantes. L'autre, le *Pomophactus Egertoni* parait former un type à part par ses grands sous-orbitaires qui recouvrent les joues. Les exemplaires de *Calopomus* que j'ai dû placer provisoirement dans cette famille sont trop incomplets pour que je puisse me prononcer définitivement sur la place que ce poisson doit occuper. Les écailles assez grandes qui distinguent ce genre et qui ne se retrouvent pas dans la famille des Teuthies devront être soumises à un examen approfondi, lorsqu'on possédera un plus grand nombre d'échantillons mieux conservés.

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characters that the genus *Sciænurus*, which I had placed provisionally among the *Sciænoidæ*, effectively belongs to the *Sparoidæ*, and ought to be placed in the vicinity of the *Dentices*.

The family of the *Teuthiæ* is characterized by a tolerably marked separation between the occiput and the anterior portion of the head comprising the frontals and the other contiguous bones. The general forms of the head vary considerably; however, there is always a small occipital crest, rather thin and fragile, as well as parietal and temporal crests. The intervals which separate these crests are not true grooves, or at least they are not deeper than the surface of the cranium in general, and the crests rather resemble small sharp-edged plates placed on this uniformly vaulted surface. The frontals are in general large and strong, they are thicker than in any other family, and exhibit various patterns in the arrangement of their osseous fibres. Most frequently they present fine meshes or closely-pressed pores; the under surface of the cranium forms a sharp-edged keel throughout the whole length of the sphenoid.

Up to the present time I am acquainted with three genera belonging to this family, which are found in the London clay: one, the *Ptychocephalus radiatus*, approaches closely to *Amphacanthus*; another, the *Pomophactus Egertoni*, appears to form a distinct type from its large suborbitals which cover the cheeks. The specimens of *Calopomus* which I have been compelled to place provisionally in this family, are too imperfect to enable me to decide definitively on the place which this fish should occupy. The tolerably large scales which distinguish this genus, and which are not met with in any other of the family of the *Teuthiæ*, must be submitted to minute investigation when we are in possession of a larger number of better-preserved fragments.

Les autres familles de Cténoïdes n'ont pas encore de représentans dans l'argile de Londres.

Parmi les *Cycloïdes acanthoptérygiens* la famille des *Xiphioïdes* est largement représentée par quatre genres dont l'un le *Tetrapterus* compte aussi un ressortissant vivant, tandis que les autres, les genres *Acestrus, Phasganus* et *Cœlorhynchus* n'ont existé que pendant l'époque tertiaire. Les caractères des Xiphioïdes sont tellement tranchés qu'il est presque inutile d'y revenir. L'absence totale de crête quelconque sur toute la face supérieure du crâne qui est uniformément incliné et rectiligne feront toujours facilement distinguer cette famille de toutes les autres, et surtout des Scombéroïdes avec lesquels on les a confondus jusqu'ici.

La famille des *Scombéroïdes* restreinte aux limites que je lui ai assignées dans les 'Recherches sur les Poissons Fossiles,' v. i. p. 16^{e} et suiv., présente deux types de crânes assez différents, en rapport avec la forme générale du corps. Dans les vrais Scombéroïdes, la face supérieure du crâne est presque tout d'une venue. La crête occipitale mitoyenne est haute; elle avance toujours sur les frontaux, où elle est double, et très souvent les frontaux eux-mêmes sont relevés au milieu jusque vers le nasal. Les crêtes pariétales sont minces et considérablement relevées; elles sont parallèles à la crête mitoyenne et viennent se perdre le plus souvent au milieu du bord supérieur de l'orbite. Les frontaux sont très-souvent squammeux dans leur partie antérieure, et ce caractère est développé d'une manière extraordinaire dans le genre Cœlopoma de l'argile de Londres. Les crêtes temporales sont très-fortes; elles se réunissent au haut de l'orbite avec les crêtes pariétales, et sont presque aussi minces et tranchantes que ces dernières. Une fosse latérale externe est encore formée par le bord externe du frontal postérieur, qui descend séparément de la crête temporale.

The other families of *Ctenoidæ* have as yet no representatives in the London clay.

Among the Acanthopterygian *Cycloids* the family of the *Xiphioidæ* is abundantly represented by four genera, one of which, *Tetrapterus*, likewise counts a living representative, while the other genera, *Acestrus*, *Phasganus* and *Cœlorhynchus*, existed only during the tertiary epoch. The characters of *Xiphioidæ* are so marked that it is almost useless to return to them. The total absence of any crest whatsoever over the whole upper surface of the cranium, which is uniformly inclined and rectilinear, will always allow of this family being readily distinguished from all others, and especially from the *Scomberoidæ*, with which they have hitherto been confounded.

The family of the *Scomberoidæ*, confined within the limits I have assigned to it (in the 'Récherches sur les Poissons Fossiles,' vol. i. p. 16, *et seq.*,) presents two very different types of crania in relation to the general form of the body. In the true *Scomberoidæ* the upper surface of the cranium is nearly all of a piece. The central occipital crest is high, it always encroaches on the frontals where it is double, and very frequently the frontals themselves are raised in the middle as far as the nasal. The parietal crests are thin and considerably raised; they are parallel to the central crest, and most frequently disappear towards the centre of the upper margin of the orbit. The frontals are very often squamose in their front portion, and this character is developed in an extraordinary manner in the genus *Cœlopoma* of the London clay. The temporal crests are very strong, they unite above the orbit with the parietal crests, and are almost as thin and sharp-edged as the latter. An external lateral groove is moreover formed by the external margin of the posterior frontal, which descends separately from the temporal crest.

Il est assez difficile de distinguer de prime abord les Sparoïdes des Scombéroïdes qui ont les uns et les autres les mêmes crètes à l'occiput, cependant dans la plupart des Scombéroïdes, la crète mitoyenne se prolonge sur les frontaux, ce qui n'est pas le cas dans les Sparoïdes. D'un autre côté, les crètes pariétales convergent en avant chez les Sparoïdes, tandis que dans les Scombéroïdes, elles sont parallèles à la crète mitoyenne ou bien même divergentes en avant. Enfin ce qui distingue encore les Sparoïdes c'est le museau prolongé en quille et la ligne brisée de la surface du crâne, tandis que dans les Scombéroïdes cette surface est tout d'une venue et le museau beaucoup plus court. Le second type des Scombéroïdes n'est représenté que par la Dorée (Zeus Faber) et quelques poissons peu nombreux qui s'en rapprochent. Malgré la forme comprimée et élevée de la tête, la crète occipitale manque complètement à ce poisson. Les pariétaux qui, dans les autres Scombéroïdes, sont séparés par l'occipital supérieur, se touchent ici sur la ligne médiane. J'ai déjà indiqué dans les Recherches sur les Poissons fossiles qu'il serait possible que le Zeus Faber devant le type d'un groupe à part, et cette prévision paraît confirmée par l'ostéologie de la tête.

Les Scombéroïdes sont représentés par plusieurs genres, dont l'un, le Cybium, compte aussi des représentans dans l'époque actuelle, tandis que les *Cœlopoma*, les *Bothrosteus* et les *Cœlocephalus* n'ont encore été trouvés jusqu'ici que dans les terrains tertiaires.

Les *Sphyrénoïdes* sont représentés dans l'argile de Londres par le genre Sphyrænodus, dont les dents formidables rappellent les véritables Sphyrènes, mais dont je ne connais jusqu'ici que des machoires. Quoique je n'aie pas encore eu l'occasion de comparer de nouveau le crâne des Sphyrènes vivantes avec celui des Sphyrénoïdes tertiaires et crétacés n'ayant pas les fossiles sous

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It is somewhat difficult to distinguish at first sight the *Sparoidæ* from the *Scomberoidæ*, both of which have the same crests on the occiput; however, in the majority of the *Scomberoidæ* the central crest is prolonged over the frontals, which is not the case in the *Sparoidæ*. On the other hand, the parietal crests converge anteriorly in the *Sparoidæ*, while in the *Scomberoidæ* they are parallel to the central crest, or even divergent anteriorly. What, moreover, distinguishes the *Sparoidæ* is the snout prolonged in the form of a keel, and the interrupted line on the surface of the cranium, while in the *Scomberoidæ* this surface is continuous, and the snout much shorter. The second type of the *Scomberoidæ* is only represented by the Doreys (*Zeus Faber*), and some fish, few in number, which are allied to it. Notwithstanding the compressed and elevated form of the head, the occipital crest is totally wanting in this fish. The parietals, which in the other *Scomberoidæ* are separated by the upper occipital, here touch on the median line. I have already indicated, in the 'Récherches sur les Poissons Fossiles,' that it was probable that the *Zeus Faber* would become the type of a separate group, and this supposition appears to be confirmed by the osteology of the head.

The *Scomberoidæ* are represented by several genera, one of which, *Cybium*, has likewise representatives in the present period, while *Cœlopoma*, *Bothrosteus* and *Cœlocephalus* have hitherto only been found in the tertiary beds.

The *Sphyrænoidæ* are represented in the London clay by the genus *Sphyrænodus*, whose formidable teeth call to mind the true *Sphyrænæ*, of which, however, I am as yet only acquainted with the jaws. Although I have not yet had occasion to make a fresh comparison between the cranium of the recent *Sphyrænæ* and that of the tertiary and cretaceous la main, je crois cependant devoir en éliminer dès à présent le genre Hypsodon qui, par son crâne aplati et depourvu de fosses, me paraît plutôt appartenir á la famille des Scomberésoces. Le genre Sphyræna au contraire a des fosses occipitales distinctes sépareés par une crète mince, et des fosses temporales très profondes de forme triangulaire, qui s'avancent jusqu'au dessus de l'orbite. Il n'a point cette dépression frontale qui distingue le genre Hypsodon.

Les *Labroïdes* ont l'occiput conformé à peu près de la même manière que les Scombéroïdes. On y trouve les mêmes crètes, mais beaucoup plus raccourcies. La crète mitoyenne ne s'avance jamais sur les frontaux; elle est limitée à l'occipital supérieur. Les crètes pariétales n'atteignent jamais le bord supérieur de l'orbite, mais s'arrêtent vis à vis de son bord postérieur. Les fosses pariétales sont beaucoup moins profondes. Une fosse assez profonde se trouve aussi sur la partie antérieure des frontaux, et s'étend jusque vers l'endroit où le nasal se joint à ces derniers. Il y a en outre une articulation particulière des pharyngiens au dessous du grand trou occipital.

Les *Blennioïdes* se reconnaissent au premier coup d'œil à la singulière conformation de leur crâne. L'occiput est applati en arrière et forme un triangle presque équilatéral, dont le sommet est tourné en avant, et se continue en une crète mitoyenne qui s'avance jusqu'au dessus de l'orbite. Ici, en arrière de l'orbite, le crâne est tellement comprimé latéralement qu'il y a à peine un espace entre ces parvis osseuses pour la partie antérieure du cerveau. Les bords postérieurs de l'orbite s'étendent latéralement sous forme de deux aîles triangulaires. L'espace compris entre les orbites est allongé et assez étroit. Les bords de l'orbite sont relevés, de sorte qu'il y a un sillon quelquefois assez profond au milieu du front. Cette absence de crète mitoyenne sur

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Sphyrænoidæ, not having the fossils at my disposal, I am however induced to remove from it, even at present, the genus *Hypsodon*, which appears to me, from its flattened cranium, which is deprived of grooves, rather to belong to the family of the *Scomberesocidæ*. The genus *Sphyræna*, on the contrary, has distinct occipital grooves separated by a thin crest and very deep temporal grooves, of a triangular form, which advance beyond the orbit. There is not that frontal depression which distinguishes the genus *Hypsodon*.

The *Labroidæ* have the occiput shaped nearly in the same manner as the *Scomberoidæ*; we find the same crests, only much more shortened. The central crest never advances over the frontals, it is restricted to the upper occipital. The parietal crests never attain the upper margin of the orbit, but stop opposite its posterior margin. The parietal grooves are far more shallow. A tolerably deep groove is likewise met with on the anterior portion of the frontals, and extends to the place where the nasal joins these latter. There is besides a peculiar articulation of the pharyngians below the large occipital aperture.

The *Blennioidæ* are recognised at first sight from the singular conformation of their cranium. The occiput is flattened posteriorly, and forms nearly an equilateral triangle, whose summit is directed anteriorly, and is continued in a central crest, which advances to just above the orbit. Here, behind the orbit, the cranium is compressed to such a degree laterally that there is scarcely space between the osseous walls for the anterior portion of the brain. The hinder margins of the orbit extend laterally in form of two triangular wings. The space comprised between the orbits is elongated and somewhat narrow. The margins of the orbit are raised, so that there is sometimes a tolerably profound furrow in the middle of the front. This absence of a l'occiput, tandis qu'il en existe une au dessus des fosses mastoïdiennes est un caractère tout particulier qui n'existe que dans cette famille. La séparation des Blennoïdes d'avec les Gobioïdes ne pourrait être mieux justifiée que par les types si entièrement différens de leurs crânes. La face inférieure du crâne forme une quille tranchante qui est surtout relevée entre les yeux. Le seul représentant de cette famille que j'ai trouvé dans l'argile de Londres, le *Laparus alticeps*, se rapproche par la forme de son crâne du Loup de Mer, *Anarrhichas Lupus*. Je ne connais pas encore sa dentition.

La famille des *Scomber-Esoces* établie dernièrement par M. Müller pour plusieurs poissons Malacoptérygiens dont les os pharyngiens inférieurs sont réunis en une seule pièce; a pour représentans principaux les Exocetus, les Hemiramphus, et les Orphies (Belone). Quoique les formes extérieures de ces genres soient très-différentes, je n'en trouve pas moins une grande analogie dans l'ostéologie de leur tête. La face supérieure du crâne est entierèment aplatie, sans crète saillante ni fosse distincte. L'occipital supérieur est extrèmement petit, prolongé en arrière, non point en une crète, mais en une pointe assez grèle et courte. Le milieu du front est un peu déprimé. Le bord de l'orbite, au lieu d'être relevé comme dans les Joues cuirassées, avec lesquelles les Scomberésoces ont le plus d'analogie, est abaissé vers les côtés. Le genre Hypsodon paraît appartenir à cette curieuse famille, et la preuve en sera fournie irrévocablement dès que l'on trouvera un exemplaire dont la face inférieure du crâne offrira cette articulation propre sur laquelle les pharyngiens sont fixés dans tout ce curieux groupe que M. Müller à désigné sous le nom de *Pharyngognathes*.

Les *Clupéïdes* se distinguent par un caractère tout particulier de leur crâne, la prolongation de deux crêtes pariétales en arrière sous forme d'é-

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central crest on the occiput, while one exists above the mastoidian grooves, is quite a peculiar character, which exists only in this family.

The separation of the *Blennioidæ* from the *Gobioidæ* could not be better justified than by the entirely different types of their crania. The lower surface of the cranium forms a sharp-edged keel, which is especially raised between the eyes. The only representative of this family which I have found in the London clay, *Laparus alticeps*, is allied, by the form of its cranium, to the Sea-wolf *Anarrhichas Lupus*. I am not acquainted with its dentition.

The family of the *Scomberesocidæ*, recently established by M. Müller, for several Malacopterygian fish, the lower pharyngeal bones of which are united into a single piece, is principally represented by the *Exocetus*, *Hemiramphus* and *Belone*. Although the external forms of these genera are very different, I nevertheless find a great analogy in the osteology of their head. The upper face of the cranium is entirely flattened without any prominent crest or distinct groove. The upper occipital is extremely small, prolonged backwards, not into a crest, but into a somewhat thin and short point. The centre of the front is slightly depressed; the margin of the orbit, instead of being raised as in the *Cottoidæ* with which the *Scomberesocidæ* have most analogy, is lowered towards the sides. The genus *Hypsodon* appears to belong to this curious family, and the proof will be irrevocably furnished as soon as a specimen shall have been found with the lower surface of the cranium presenting that peculiar articulation, on which the pharyngeals are attached throughout this curious group, which M. Müller has designated by the name of '*Pharyngognathes*.'

The *Clupeidæ* are distinguished by a very peculiar character of their cranium, the prolongation of two parietal crests hindwards in the form of pines émoussées ce qui fait que la petite crète occipitale se trouve placée dans le sinus antérieur d'une profonde entaille triangulaire. De ce sinus partent en même temps deux saillies divergentes qui viennent mourir au milieu du bord supérieur de l'orbite, et entre lesquelles se trouve placé un enforcement assez considérable de forme triangulaire qui occupe le milieu du front. Les fosses temporales sont assez considérables; leur extrémité antérieure s'efface au bord postérieur de l'orbite. Les frontaux antérieurs et postérieurs forment de grandes éminences latérales. Ce qui caractérise surtout la face inférieure ce sont deux prolongemens en forme d'aîle qui partent de l'extremité postérieure du sphénoïde et s'adaptent latéralement sur les côtés de la colonne vertébrale.

Je n'ai trouvé que deux genres dans l'argile de Londres dont l'un le genre *Megalops* a des représentans vivans; tandis que l'autre le genre *Halecopsis* est complètement éteint.

J'ai rangé provisoirement dans la famille des *Characins*, sous le nom de *Brychetus Mulleri*, une énorme tête fossile, dont les mâchoires sont armeés d'une série de dents très allongées. Cette tête se distingue en outre par un caractère très tranché, c'est que le pourtour de la bouche est formé en avant par les intermaxillaires supérieurs qui portent également des dents. C'était le caractère qui distinguait mon ancienne famille des Halécoïdes que le prince de Canino a le premier demembrée, et que M. Müller à plus tard si heureusement subdivisée en plusieurs familles très-bien caractérisées. Le Brychetus ne peut appartenir qu'aux Characins ou aux Célacanthes; mais n'ayant pas encore pu me procurer des squelettes d'un Characin vivant ni des écailles de ce fossile, je dois attendre pour le classer définitivement de plus amples renseignemens, qui ne manqueront point, je l'espère, puisque la grandeur de cette espèce doit nécessairement attirer l'attention des collecteurs.

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two blunt spines, so that the small occipital crest is situated in the anterior sinus of a deep triangular notch. From this sinus part together two diverging crests, which disappear in the centre of the upper margin of the orbit, and between which occurs a very considerable depression of triangular form occupying the middle of the front. The temporal grooves are somewhat considerable; their anterior extremity becomes obliterated at the posterior margin of the orbit. The anterior and posterior frontals form large lateral eminences. What especially characterizes the lower surface, are two wing-shaped prolongations which proceed from the posterior extremity of the sphenoid, and adapt themselves laterally to the sides of the vertebral column.

I have only found two genera in the London clay, one of which, *Megalops*, has living representatives, while the other, the genus *Halecopsis*, is entirely extinct.

I have arranged provisionally in the family of the *Characidæ*, under the name of *Brychetus Mulleri*, an enormous fossil head, the jaws of which are provided with a series of very long teeth. This head is moreover distinguished by a very marked character, the circumference of the mouth being formed in front by the upper intermaxillaries, which likewise are furnished with teeth. This was the character which distinguished my old family the *Halecoidæ*, which the Prince of Canino was the first to dismember, and which M. Müller subsequently subdivided with so much judgement into several well-characterized families. The *Brychetus* can belong only to the *Characes* or to the *Celacanthi*, but having hitherto been unable to obtain skeletons of a recent *Characes* or scales of this fossil, I must wait for ample information in order to classify it definitively, which I hope will not be wanting, as the size of this species will necessarily attract the attention of collectors.

La famille des *Gadoïdes* présente des variations assez notables à l'égard de la crête occipitale, dans des genres qui, sous d'autres rapports, sont assez rapprochés. C'est ainsi que chez les Motelles, les Merluches, les Lottes et les Phycis, la crête s'étend en arrière, sans s'élever au dessus du plan général de l'occiput, tandis que dans les Merlans et les Gades proprement dits, la crête s'avance jusqu'au dessus des orbites en s'élevant sensiblement au dessus de l'occiput. L'occiput in général est large, de forme triangulaire et a, comme tout le crâne, un aspect foliacré. Les os en général sont tres minces, retenus dans leur position par le développement considérable des cartilages craniens. Les crètes sont des lames très minces, mais les fosses de l'occiput sont en général très peu accusées ; le front est rétréci entre les orbites et des prolongemens particuliers du frontal forment, chez le plupart des genres, des doubles bords autour des orbites. Les frontaux antérieurs s'étendent latéralement sous forme d'aîle. La partie inférieure de l'occiput est large et très bombée, sans aucune quille médiane, et c'est la boursoufflure générale de cette partie qui fait qu'on distingue facilement les Gadoïdes des autres familles, et surtout des Gobioïdes, dont ils se rapprochent le plus par le conformation des os du crâne.

Je connais jusqu'ici quatre genres de cette intéressante famille dont j'ai trouvé les premiers fossiles dans l'argile de Londres: Ce sont le *Rhinocephalus planiceps*, qui par la formation de son crâne tient le milieu entre les Merluches et les Phycis; les genres *Merlinus* et *Goniognathus*, qui se rapprochent d'avantage des Merlans; et le genre si curieux que Mr. König à appelé *Ampheristus*, et qui parait constituer un nouveau type dans la famille des Gadoïdes.

Les *Anguilliformes* forment un type tout à fait à part qui se distingue au

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The family of the *Gadoidæ* presents considerable variations with respect to the occipital crest in genera which in other respects are nearly allied. Thus, for instance, in the *Motellæ*, the *Merlucci*, the *Lotæ*, and the *Phycis*, the crest extends posteriorly without rising above the general level of the occiput, while in the Whitings and the Cods, properly so called, the crest advances to just above the orbits, rising gradually above the occiput. The occiput is in general broad, of triangular form, and, like the whole of the cranium, has a foliaceous appearance. The bones are in general very thin, held in their position by the considerable development of the cranial cartilages. The crests consist of very thin laminæ, but the grooves of the occiput are in general extremely faint; the front is contracted within the orbits, and the peculiar prolongation of the frontal, forming in most of the genera double margins around the orbits; the anterior frontals extend laterally in the form of a wing, the lower portion of the occiput is broad and much-vaulted, without any median keel; and it is the general protuberance of this part which renders the *Gadoidæ* easy to distinguish from the other families, and especially from the *Gobioidæ*, to which they most approach by the conformation of the bones of the cranium.

I am at present acquainted with four genera of this interesting family, of which I found the first fossils in the London clay. They are the *Rhinocephalus planiceps*, which, from the formation of its skull, is intermediate between *Merluccius* and *Phycis*; the genera *Merlinus* and *Goniognathus*, which are more nearly related to the Whitings; and the curious genus which M. König has called *Ampheristus*, and which appears to constitute a new type in the family of the *Gadoidæ*.

The *Anguilliformes* constitute quite a separate type, which is distinguished premier coup d'œil des Ophidioïdes, dont ils doivent être séparés comme famille à part. Toute la face supérieure de la tête est unie et lisse, sans crêtes saillantes. La surface postérieure de l'occiput se détache à angle droit de la face supérieure et présente souvent des fosses latérales, au dessus des quelles le bord supérieur de l'occiput s'avance en forme de toit. Le temporal s'avance en forme de pointe entre les frontaux principaux et postérieurs qu'il sépare completement, et le frontal postérieur est relégué derrière l'orbite, où il forme une saillie très considérable en forme de crochet. Le nasal se prolonge en arrière jusqu'au dessus du milieu de l'orbite. Le crâne en géneral est très solide, et présente le forme d'une pyramide à base triangulaire et à faces très allongées.

Le genre *Rhynchorhinus* qui est le seul représentant de cette famille dans l'argile de Londres tient à peu près le milieu entre les Murènes proprement dites et les Congres.

Pour donner une ideé de l'exactitude à laquelle on peut arriver en étudiant comparativement les poissons de Sheppy je vais donner ici une déscription de l'une des espèces les plus répandues dans cette formation, le *Sciænurus Bowerbankii.* Je joins à cette déscription une réstauration au trait de l'animal entier. (Voir la planche ci contre.) Ce poisson a le corps court, haut et très comprimé, à la manière des Sargues ou même des Dorées (Zeus). Sa hauteur, prise au bord antérieur de la nageoire anale, est contenue deux fois et demi dans sa longueur ; son épaisseur, même en tenant compte de la pression habituelle aux fossiles de Sheppy, est comprise quatre fois dans sa hauteur. Sa tête participe des mêmes caractères que le tronc ; elle est haute, comprimée et tronquée en avant. Elle est aussi longue que haute, et sa longueur est à la longueur totale du corps comme 2 à 7. Le front forme

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at first sight from the *Ophidioidæ,* from which they should be separated as a distinct family. The whole of the upper surface of the head is continuous and smooth without projecting crests. The hinder surface of the occiput separates at a right angle from the upper surface, and frequently presents lateral grooves, above which the upper margin of the occiput projects in the form of a roof. The temporal advances in form of a point between the principal and posterior frontals, which it separates entirely, and the posterior frontal is removed to behind the orbit, where it forms a considerable hooked projection. The nasal is prolonged posteriorly to just above the middle of the orbit. In general the cranium is very solid, and presents the form of a pyramid, with triangular base and very lengthened sides.

The genus *Rhynchorhinus,* which is the only representative of this family in the London clay, holds about the middle between the *Murænæ,* properly so called, and the Congers.

To give an idea of the accuracy to which it is possible to attain in making a comparative study of the Sheppey fish, I will give in this place a description of one of the most common species in this formation, the *Sciænurus Bowerbankii.* I add to this description an outline restoration of the entire animal. (See Plate XL.) This fish has the body short, high, and much-compressed, resembling in this respect the *Sargi,* or even the Doreys (*Zeus*). Its height, taken at the front margin of the anal fin, is contained twice and a half in its length ; its thickness, even taking into consideration the pressure common to the Sheppey fossils, is comprised four times in its height ; its head participates in the same characters as the trunk ; it is high, compressed, and anteriorly truncated. It is as long as high, and its length is to the total length of the body as two to seven. The front forms a straight line, de-une ligne droite déscendant obliquement depuis une saillie au dessus des yeux. Le nuque est presque horizontale, s'élevant insensiblement vers la nageoire dorsale. Le museau est tronqué presque verticalement et forme une carène tranchante.

L'œil est très-grand et comprend plus du tiers de la hauteur totale de la tête. Il est placé très-haut, presque à fleur de front, au milieu entre le bout du museau et le bord postérieur du préopercule. La capsule sclérotique qui l'entoure est assez forte et conservée dans la plupart des exemplaires.

La constitution du crâne offre quelques particularités frappantes ; sa face supérieure présente une ligne brisée en trois parties presque égales. La partie postérieure ou la nuque est oblongue, insensiblement rétrécie d'arrière en avant et divisée en deux parties par la crête mitoyenne du crâne qui, à ce qu'il paraît, était très mince et très haute. Cette crête mitoyenne s'étend en arrière, jusque vers le premier rayon de la dorsale. Les deux crêtes pariétales qui circonscrivent cette partie oblongue supérieure de la nuque sont très marquées, mais assez minces; elles s'étendent considérablement en arrière, où elles forment l'articulation du supra-scapulaire ; elles se prolongent également dans l'angle saillant au dessus des yeux. Il en est de même de la crête mitoyenne. Les deux fosses pariétales s'étendaient ainsi jusqu'au dessus des yeux en se rétrécissant insensiblement et en s'élevant au niveau du front. La surface de la nuque formait par conséquent une espèce de toit allonge, relevé sur la ligne médiane et bordé des deux côtés par les crêtes pariétales. L'os occipital supérieur s'avance en biseau aussi loin que la crête mitoyenne, entre les deux frontaux qui s'étendent en arrière jusqu'à la moitié de la longueur de la nuque. Trois os participent à la formation des crêtes pariétales: l'occipital externe en arrière, l'os pariétal au milieu et l'os frontal dans la

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scending obliquely from a prominence above the eyes; the nape is nearly horizontal, rising gradually towards the dorsal fin. The snout is almost vertically truncated, and forms a sharp-edged keel.

The eye is very large and occupies more than a third of the total height of the head; it is placed very high, nearly on a level with the forehead, in the centre between the end of the snout and the posterior margin of the preoperculum. The sclerotic capsule which surrounds it is strong and well-preserved in the majority of the specimens.

The construction of the cranium presents several striking peculiarities; its upper surface exhibits a line broken into three nearly equal portions; the hinder portion, or the nape, is oblong, gradually contracted from behind anteriorly, and divided into two portions by the central crest of the cranium, which appears to have been very thin and very high. This central crest extends hindwards as far as the first dorsal ray. The two parietal crests which circumscribe this upper oblong portion of the nape, are very prominent but somewhat slender; they extend for a long way hindwards, where they form the articulation of the suprascapulary ; they likewise extend into the projecting angle above the eyes. The same is the case with the central crest; the two parietal grooves extended therefore to above the eyes, becoming gradually smaller, and rising to the level of the front. The surface of the nape consequently formed a sort of elongated roof raised on the median line, and bounded on the two sides by the parietal crests. The superior occipital bone advances, *en biseau*, as far as the central crest, between the two frontals, which extend hindwards half the length of the nape. Three bones concur in the formation of the parietal crests; the external occipital behind, the parietal bone in the partie antérieure. Les faces latérales de la nuque déscendent presque perpendiculairement pour se relever ensuite de nouveau et former les puissantes crêtes temporales, sur lesquelles sont articulés les opercules. Les fosses temporales qui sont formées par ces crêtes s'élèvent insensiblement vers la saillie du front; mais elles n'atteignent pas la longueur des fosses pariétales. Enfin, au dessous de ces fosses se trouvent encore deux petites fosses mastoïdiennes comprises entre le frontal postérieur et la crète temporale qui se continue derrière le préopercule, sur l'opercule. Le front est entièrement formé par les deux frontaux; il forme une surface tout à fait plane, qui est même un peu déprimée sur la ligne médiane, au lieu d'être relevée comme dans beaucoup d'autres poissons. Les frontaux sont plus larges en arrière qu'en avant et leurs parties orbitaires déscendent en arc des deux côtés. Cet arc est complété en avant par le frontal antérieur, au dessus duquel les frontaux principaux finissent brusquement comme tronqués.

Le nasal s'enchasse entre les deux frontaux principaux par un bouton aplati, dont la face supérieure continue la surface du front; mais plus loin il déscend presque verticalement, formant une crête tranchante et très étroite; entre cette crête et le frontal antérieur se trouve une fosse très profonde qui est limitée en avant par les sous-orbitaires et la mâchoire supérieure.

Le premier sous-orbitaire est énorme, en forme de trapézoïde à bords arrondis. Sa partie antérieure est poreuse, sa partie postérieure squammeuse et plisseé en rides rayonnant de haut en bas.

Le préopercule est long, étroit, surtout en haut, où il forme une arête qui déscend verticalement. Sa partie horizontale est très-courte, le limbe qui borde le coin de l'équerre est plissé grossièrement en rides rayonnantes.

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centre, and the frontal bone in the anterior portion. The lateral portions of the nape descend almost perpendicularly, to rise again subsequently and form the strong temporal crests on to which are articulated the opercula. The temporal grooves which are formed by these crests, rise gradually towards the projection of the front, but they never reach the length of the parietal grooves. Lastly, below these grooves are situated two smaller mastoidian grooves, comprised between the posterior frontal and the temporal crest, which continues behind the preoperculum over the operculum. The front is made up entirely of the two frontals; it forms a perfectly level surface, which is even slightly depressed on the median line instead of being raised as in many other fish. The frontals are wider behind than in front, and their orbital portions descend in the form of an arc along the two sides. This arc is completed in front by the anterior frontal, above which the principal frontals terminate suddenly as if truncated.

The nasal is encased between the two principal frontals by a flattened protuberance, the upper surface of which is a continuation of the surface of the front, but subsequently it descends almost vertically, forming a sharp-edged and very narrow crest; between this crest and the anterior frontal there is a very deep groove, which is limited anteriorly by the suborbitals and the upper jaw.

The first suborbital is of immense size, trapezoidal, with rounded margins. Its anterior portion is porous, its posterior portion squamose and folded in plaits, radiating from above downwards.

The preoperculum is long, narrow, especially above, where it forms a crest which descends vertically. The horizontal part is very short, the margin (*limbe*) by which the corner of the 'equerre' is bordered is coarsely folded in

Toute la fosse orbitaire entre le préopercule et le sous-orbitaire est recouverte d'écailles semblables à celles du corps.

Les maxillaires supérieurs sont presque entièrement cachés sous les sous-orbitaires; ils sont élargis en arrière et engrenés en avant avec la branche montante de l'intermaxillaire. Celui-ci est court, courbé en arc et garni sur son bord inférieur d'une rangée de fortes dents crochues, dont la longueur diminue d'avant en arrière.

Les maxillaires inférieurs sont courts et hauts; ils sont garnis, comme les intermaxillaires, de dents crochues qui en arrière sont en simple rangée, tandis qu'à la symphyse il y en a plusieurs placées les unes derrière les autres. Les dents diminuent en arrière de la même manière que celles de l'intermaxillaire; on ne remarque pas de canines plus saillantes que les autres. Je ne saurais dire si le palais et la langue étaient aussi garnis de dents; mais la position générique de notre poisson me fait présumer qu'ils étaient lisses.

Les pièces operculaires sont couvertes de plusieurs rangées d'écailles tout à fait semblables à celles du corps. L'opercule lui-même était beaucoup plus haut que long, et formait un trapézoide à angles postérieurs arrondis. Son bord libre est mince mais entièrement lisse, aussi bien que celui du préopercule. La ceinture thoracique est extrèmement forte, elle forme en arrière vers la gorge, un coin arrondi, au devant duquel se trouve dans un creux, l'articulation de la nageoire pectorale qui était assez petite, à ce qui paraît, mais dont je ne saurais rien dire de plus, ne l'ayant jamais vue conservée en entier.

Les nageoires ventrales étaient placées au dessous de la gorge, peut-être même un peu plus en avant que les pectorales.

La dorsale commence immédiatement derrière la nuque par des épines

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radiating plaits. The whole of the orbital fossa between the preoperculum and the suborbital is coated with scales resembling those of the body.

The upper maxillaries are almost entirely hidden under the suborbitals; they are widened behind, and in connection anteriorly with the ascending branch of the intermaxillary, which is short, curved like a bow, and furnished on its lower margin with a series of strong, crooked teeth, whose length diminishes from the front hindwards.

The inferior maxillaries are short and high; they are provided like the intermaxillaries with crooked teeth, which hindwards are in simple rows, while at the symphysis there are several placed one behind the other. The teeth diminish hindwards in the same manner as those of the intermaxillary; the canines are not observed to be more projecting than the others. I am not able to say whether the palate and the tongue were likewise provided with teeth, but the generic position of our fish leads me to presume that they were smooth.

The opercular pieces are covered with several rows of scales perfectly similar to those of the body. The operculum itself was much higher than long, and formed a trapezoid with rounded posterior angles. Its free margin is thin but entirely smooth, which is also the case with that of the preoperculum. The thoracic girdle is extremely strong; it forms hindwards towards the throat a rounded angle, in front of which, situated in a hollow, is the articulation of the pectoral fin, which was rather small, at least so it appears, but of which I am able to say nothing further, never having seen it preserved entire.

The ventral fins were placed beneath the throat, perhaps even a little more in front than the pectorals.

The dorsal fin begins directly behind the nape with very strong and long très fortes et longues; elle paraît finir au commencement du dernier tiers de la longueur totale. Je présume que ses derniers rayons étaient mous, et qu'il n'y avait pas de séparation dans la nageoire entre les deux espèces de rayons.

L'anale commence presque au milieu du corps; elle est étroite mais longue, et pouvait avoir une quinzaine de rayons, dont les trois premiers sont épineux.

La caudale n'est pas encore connue en détail; ses rayons sont couverts à la base par de petites écailles très serrés. La ligne latérale décrit une courbe parallèle à celle du dos, occupant en haut le premier tiers de la hauteur totale du corps. Les écailles qui recouvrent tout le corps sont assez grandes et très minces, de sorte que le bord postérieur est rarement consérvé. Examinées à la loupe, ces écailles présentent de nombreuses lignes concentriques, très serrées les unes contre les autres, et munies dans leur partie antérieure d'une douzaine de sillons en éventail qui sont visibles à l'œil nu. Les lignes concentriques se perdent sur le champ postérieur de l'écaille, où l'on voit de petites granulations qui deviennent des dentelures extrèmement exigues sur le bord libre de l'écaille, et qui devaient tomber facilement même pendant la vie, car je ne les ai trouvées conservées que sur quelques écailles peu nombreuses.

En résumé, le *Sciænurus Bowerbankii* est un Cténoïde acanthoptérygien thoracique ayant les joues écaillées et le bord postérieur des pièces operculaires lisse; les mâchoires armés de dents crochues et égales; les os du crâne assez solides, à crêtes minces. Un caractère particulier réside dans les sous-orbitaires énormes, et dans la présence d'une seule dorsale et d'une seule anale.

Si maintenant nous cherchons à déterminer la place de ce poisson dans la classification actuelle, nous ne trouverons qu'une seule famille d'Acanthoptérygiens cténoïdes à laquelle il puisse être associé, celle des Sparoïdes, qui

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spines; it appears to terminate at the commencement of the last third of the total length. I presume that its last rays were soft, and that there was no separation between the two kinds of rays in the fin.

The anal commences near the middle of the body; it is narrow but long, and may have possessed about fifteen rays, the first three of which were spinous.

The caudal is not yet known in detail; its rays are covered at the base by very close, minute scales. The lateral line describes a curve parallel to that at the back, occupying at top the first third of the total height of the body. The scales which cover the entire of the body are somewhat large and very thin, so that the posterior margin is rarely preserved. Examined under the microscope, these scales present numerous concentric lines, very close upon each other, and furnished in their anterior portion by a dozen grooves arranged like a fan, which are visible to the naked eye. The concentric lines disappear on the hinder portion of the scale, where we see small granulations which become excessively minute denticulations on the free margin of the scale, and which fell off easily during life, for I have never found them preserved except on some few scales.

In fact, *Sciænurus Bowerbankii* is an Acanthopterygian *thoracic Ctenoid*, having scaly cheeks, the hinder margin of the opercular pieces smooth, and the jaws furnished with crooked and equal teeth; the bones of the cranium rather solid with thin crests. A peculiar character is found in the enormous suborbital, and in the presence of a single dorsal and of a single anal.

Now if we endeavour to determine the place of this fish in the present system of classification, we find but a single family of Acanthopterygian Ctenoids with which it can be associated, that of the *Sparoidæ*, which, while they have tout en ayant les bords operculaires lisses, participe des autres caractères des Percoïdes. En effet, voici quels sont les caractères assignés par Cuvier à ses Sparoïdes. "Les pièces operculaires sont dénuées de dentelures et d'épines; les os de la tête sont solides, mais non point caverneux comme chez les Sciénoïdes. Le palais est dénué de dents; les rayons épineux et les rayons mous réunis en une seule dorsale. Les joues et le corps sont couverts d'écailles, qui d'après mes recherches ont pour caractère d'avoir peu de dentelures au bord postérieur, encore ces dentelures sont elles très faibles et tombent facilement. Les Sparoïdes se distinguent des Sciénoïdes par l'absence de creux caverneux dans les os de la tête; par le manque d'écailles sur les nageoires, l'absence d'épines ou de dentelures sur les pièces operculaires. Ce dernier caractère les distingue aussi des Percoïdes." C'est donc parmi les Sparoïdes qu'il faut placer le genre Sciænurus. Cuvier a déjà divisé cette famille en plusieurs tribus d'après leur dentition, il n'y en a qu'une seule, celle des Dentés (Dentex) qui soit entièrement dépourvue de molaires arrondies, et chez laquelle on ne trouve que des dents crochues et coniques ordinairement sur un seul rang. J'ai comparé le squelette du *Dentex vulgaris* avec celui du Sciænurus. On y retrouve les mêmes caractères, mais la division de la surface supérieure du crâne en trois parties n'est pas aussi bien marquée, et surtout le front n'est pas aussi développé que chez le Sciænurus. En revanche on y retrouve la même quille du nasal; les fosses pariétales forment un oblong allongé et bordé par deux crètes pariétales, relevées et minces, les mêmes fosses temporales profondes et séparées des fosses mastoïdiennes particulières. On rencontre en outre chez les Dentés la même forme du préopercule avec son arète verticale et son limbe étroit, et dans toute la famille des Sparoïdes cet énorme sous-orbitaire qui cache presque la totalité du maxillaire supérieur. Cuvier a distingué des véritables

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smooth opercular margins, possess in other respects the characters of the *Percoidæ.* The following in fact are the characters assigned by Cuvier to his *Sparoidæ*:—" The opercular pieces are not furnished with denticulations or spines; the bones of the head are solid, but not hollow, as in the *Sciænoidæ.* The palate is not furnished with teeth; the spiny and the soft rays are united into a single dorsal. The cheeks and the body are covered with scales, which, according to my researches, are characterized by their having few denticulations on the posterior margin; moreover this toothed structure is very weak, and easily falls off. The *Sparoidæ* are distinguished from the *Sciænoidæ* by the absence of cavities in the bones of the head, by a want of scales on the fins, by the absence of spines or of denticulations on the opercular pieces. This latter character distinguishes them likewise from the *Percoidæ.*" The genus *Sciænurus* must therefore be placed among the *Sparoidæ.* Cuvier has divided this family into several tribes according to their dentition; there is only one, that of *Dentex,* which is entirely deprived of rounded molars, and in which none but hooked and conical teeth, generally arranged in a single row, are found. I have compared the skeleton of *Dentex vulgaris* with that of *Sciænurus.* The same characters are met with, but the division of the upper surface of the cranium into three parts is not so marked, and the front is likewise not so developed as in *Sciænurus.* However, the same keeled nasal is found; the parietal fossæ form an elongated oblong, bordered by two raised and thin parietal crests, the temporal grooves are similar and separated from the peculiar mastoidian grooves. We moreover find in the *Dentices* the same form of the preoperculum, with its vertical crest and its straight border, and in the whole family of the *Sparoidæ* the enormous subor-

Dentés le genre des Pentapodes qui comprend des espèces à bouche moins fendue, à tête très écailleuse, et à caudale écailleuse jusqu'au bout. C'est à côté de ce genre qu'il faut placer notre Sciænurus. Ce qui le distingue c'est son corps comprimé et élevé, tandis que les Pentapodes ont le corps fusiforme et allongé. Il se distingue en outre par sa dentition; les Dentés ont comme les Pentapodes des dents inégales; les Pentapodes ont deux fortes canines qui surgissent entre plusieurs autres dents crochues plus petites placées en arrière entre des dents en velour ras. Le genre Sciænurus n'a point de canines, ses dents diminuent d'une manière égale d'avant en arrière; elles sont toutes crochues. Mais tout en se rapprochant des Pentapodes par la caudale écaillée à la base, il se place d'un autre côté près des Dentés par son corps comprimé. Mon genre Sparnodus dont j'ai décrit plusieurs espèces de Monte Bolca, se rapproche aussi du genre Sciænurus par l'uniformité de ses dents, mais il en diffère en ce que ses dents sont courtes et très-obtuses.

Je connais maintenant deux espèces du genre Sciænurus, provenant toutes deux de l'argile de Londres, de Sheppy.

Il faut être sur ses gardes pour ne pas confondre avec les Sciænurus les fragmens d'une espèce de Myripristis qui s'en rapproche beaucoup par sa forme générale, mais qui en diffère par les rides saillantes de l'opercule et par la structure des écailles. Ce n'est que par un examen très-approfondi de tous les exemplaires que j'ai eus à ma disposition que j'ai réussi à déterminer exactement ce genre; mais il se pourrait bien qu'entre les échantillons que j'ai étiquetés dans les collections d'Angleterre il se trouvât quelque fragment de Myripristis sous le nom de Sciænurus.

Après ces détails venons-en à examiner les caractères d'ensemble des

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bital which nearly hides the whole of the superior maxillary. Cuvier distinguished from the true *Dentices* the genus *Pentapodes*, which comprises the species, having the mouth less divided, with very scaly head and caudal scaly to the end. It is by the side of this genus that *Sciænurus* should be arranged; its compressed and raised body distinguishes it, while in the *Pentapodes* the body is fusiform and elongated. It is moreover characterized by its dentition; the *Dentices*, like the *Pentapodi*, have the teeth unequal; the *Pentapodi* have two strong canines, which are situated between several other smaller hooked teeth, placed behind the teeth *en velour ras*. The genus *Sciænurus* has no canines; its teeth diminish equally from the front hindwards; they are all hooked; but while approaching the *Pentapodi* by the caudal which has scales at the base, it is, on the other hand, related to the *Dentices* by its compressed body. My genus *Sparnodus*, of which I have described several species from Monte Bolca, likewise approaches to the genus *Sciænurus*, by the uniformity of its teeth, but it differs from it in the teeth being short and very obtuse.

I am at present acquainted with two species of the genus *Sciænurus*, both derived from the London clay of Sheppey.

It is necessary to guard against confounding the fragments of a species of *Myripristis* with the *Sciænuri*, to which they approach considerably in their general form, but differ from them by the prominent striæ of the operculum, and by the structure of the scales. It is only by a very minute examination of all the specimens which I have had at my disposal, that I have succeeded in accurately determining this genus; it is however possible that among the specimens which I labelled in the English collections, some fragment of *Myripristis* may occur under the name of *Sciænurus*.

After these details we will now examine the collective characters of the poissons fossiles de Sheppy. J'ai fait d'après l'excellente monographie des poissons Anglais de Mr. Yarrell, le relevé de tous les poissons de mer des côtes d'Angleterre. La comparaison de ce relevé avec celui des poissons de Sheppy donne des résultats assez curieux. Voici les chiffres auxquels je suis arrivé.

Les côtes de l'Angleterre sont habités par 155 espèces qui se répartissent dans 81 genres. Les différentes familles sont représentées de la manière suivante:

Cténoïdes.

Percoïdes*	7	espèces dans	5	genres.
Sparoïdes	7	...	5	...
Sciænoïdes	2	...	2	...
Cottoïdes	16	...	6	...
Gobioïdes†	6	...	1	..
Aulostomes	1	...	1	...
Mugiloïdes	3	..	1	...
Pleuronectes	18	...	5	...
	60		26	

Cycloïdes Acanthoptérygiens.

Scombéroïdes‡	11	espèces dans	9	genres.
Xiphioïdes	1	...	1	...
Tænioïdes	5	...	5	...
Athérines	1	...	1	...
Labroïdes	13	...	4	...
Blennioïdes§	10	...	7	...
Lophioïdes	1	...	1	...
Trachinides‖	2	...	1	...
Discoboles	5	...	3	...
Echénéides	1	...	1	...
	42		28	

Cycloïdes Malacoptérygiens.

Scomberésoces	4	espèces dans	3	genres.
Clupéides	8	...	3	...
Salmonides	2	...	2	...
Gadoïdes	20	...	8	...
Anguilliformes	8	...	6	...
	42		22	

* Je range dans cette famille le genre Capros et j'en sépare le genre Trachinus.

† J'en ai séparé les Blennioïdes.

‡ Le genre Brama me paraît devoir être reporté dans la famille des Scombéroïdes.

§ Famille distincte des Gobioïdes.

‖ Famille séparée des Percoïdes.

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fossil fish of Sheppey. I have drawn up, according to Mr. Yarrell's excellent monograph of the British fish, a summary of all the sea-fish of the coast of England. The comparison of this number with that of the Sheppey fish affords some rather curious results. The following are the figures to which I have arrived.

The English coasts are inhabited by 155 (163) species, which are divided among 81 genera. The different families are represented in the following manner. [See table supra.]

* I arrange under this family the genus *Capros*, and have removed from it the genus *Trachinus*.

† I have separated the *Blennioidæ*.

‡ The genus *Brama* should, in my opinion, be referred to the family of the *Scomberoidæ*.

§ A distinct family from the *Gobioidæ*.

‖ A family separated from the *Percoidæ*.

Ganoïdes (types récents).

Lophobranches	7	espèces dans	2	genres.
Gymnodontes	3	..	2	...
Sclérodermes	1	...	1	...
	11		5	

Les Cténoïdes sur 8 familles et 26 genres comptent 60 espèces. Les Cycloïdes acanthoptérygiens en comptent 50 sur 33 genres et 10 familles, les Malacoptérygiens 42 sur 22 genres et 5 familles, tandis que les Ganoïdes ne comptent que 3 familles, 5 genres et 11 espèces. Les familles les plus nombreuses sont les Gadoïdes, les Pleuronectes, les Cottoïdes, les Labroïdes, les Scombéroïdes et les Blennioïdes, tandis que les Sciænoïdes, les Xiphioïdes et plusieurs autres ne comptent qu'un fort petit nombre de représentans.

Comparons maintenant ce tableau avec celui que m'a fourni jusqu'ici l'étude des poissons osseux de Sheppy. Comme le dépôt de Sheppy appartient à des couches relativement très-récentes, l'on pouvait s'attendre à trouver dans la répartition des espèces une certaine conformité avec la manière dont les poissons vivans sont répartis de nos jours sur les côtes d'Angleterre. C'est en effet ce qui a lieu dans certaines limites; car si l'ensemble de la faune a un caractère un peu différent, il n'en est pas moins vrai que la localisation et l'association des types étaient soumises durant l'époque tertiaire à peu près aux mêmes lois que de nos jours. Je dois cependant rappeler ici ce que j'ai déjà dit au commencement de ce rapport, c'est que les études que j'a pu faire jusqu'ici portent essentiellement sur les têtes fossiles. Il reste uni autre travail que je n'ai pas encore pu entreprendre, et qui sera tout aussi indispensable que ce premier, la comparaison des écailles avec celles des poissons vivans; travail encore plus difficile, puisque ces recherches ne pourront être faites qu'à l'aide du microscope. Ayant réuni depuis longtemps

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The *Ctenoidæ* consist of 60 species, distributed among 8 families and 26 genera; the Acanthopterygian *Cycloidæ*, 50 in 33 genera and 10 families; the Malacopterygians, 42 in 22 genera and 5 families, while the *Ganoidæ* consist of but 3 families, 5 genera, and 11 species. The most numerous families are the *Gadoidæ*, the *Pleuronecti*, the *Cottoidæ*, *Labroidæ*, *Scomberoidæ*, and the *Blennioidæ*, while the *Sciænoidæ*, the *Xiphioidæ*, and several others have but a very small number of representatives.

Let us now compare this list with that furnished up to the present time by my investigation of the osseous fish of Sheppey. Since the Sheppey deposit belongs to comparatively very recent strata, it was natural to expect to find, in the distribution of the species, a certain coincidence with the manner according to which living fish are distributed at the present time on the coasts of England. This indeed obtains within certain limits; for if the collective fauna has a somewhat different character, it is not the less true that the localization and association of types were subject during the tertiary epoch to nearly the same laws as in our days. I must, however, call to mind what I have already stated at the commencement of this report, that the investigations which I have hitherto been able to make relate essentially to the fossil *crania*. I have still another investigation on hand, which I have as yet not been able to undertake, and which will be quite as indispensable as this first,—comparison of the *scales* with those of living fish, a work which is still more difficult, since these researches can only be made with the assistance of the microscope. Having for some years collected for my ichthyological in-pour mes études ichthyologiques un grand nombre d'écailles, les moyens de comparaison ne me feront pas défaut. Il est un autre inconvénient plus grave, c'est que dans la plupart des échantillons qui me sont confiés, les bords postérieurs libres des écailles sont usés et brisés. Or ce sont précisement ces bords qui fournissent les caractères les plus saillans pour la détermination rigoureuse des espèces. Quoiqu'il en soit, voici le relevé des espèces que j'ai pu déterminer jusqu'ici.

Les poissons osseux de Sheppy, que je connais maintenant, se rapportent à 37 genres, représentés par 44 espèces, et peuvent être répartis dans les familles suivantes.

Cténoïdes.

Percoïdes	7	espèces dans	7	genres.
Sparoïdes	2	...	1	...
Teuthies	3	...	3	...
	12		11	

Cycloïdes Acanthoptérygiens.

Scomberoïdes	12	espèces dans	9	genres.
Xiphioïdes	5	...	4	...
Sphyrænoïdes	2	...	1	...
Labroïdes	1	...	1	...
Blennioïdes	1	...	1	...
Athérines	1	...	1	...
	21		16	

Cycloïdes Malacoptérygiens.

Scomberésoces	3	espèces dans	2	genres.
Clupéides	2	...	2	...
Scopélines	1	...	1	...
Gadoïdes	4	...	4	...
	11		10	

Il est à remarquer que dans ce tableau les Cténoïdes ne comptent que trois familles représenteés par 11 genres et 12 espèces. Il se trouve que la famille des Percoïdes est de beaucoup la plus nombreuse, tandis que les familles les

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vestigations a large number of scales, the means of comparison will not be wanting.

There is another more serious inconvenience; it is, that in the majority of the fragments which have been entrusted to me, the free hinder margins of the scales are worn or broken. Now it is precisely these margins which furnish the most prominent characters for the accurate determination of the species. However, the following is the list of species which I have hitherto been able to determine.

The bony fish of Sheppey with which I am at present acquainted, belonged to 37 genera, represented by 44 species, and may be distributed among the following families. [See table supra.]

It should be observed that in this list the *Ctenoidæ* have but 3 families, represented by 11 genera and 12 species. It happens that the family of the *Percoidæ* is by far the most numerous, while the largest families of recent plus nombreuses des poissons actuels, savoir les Pleuronectes, les Cottoïdes et les Gobioïdes manquent complètement dans les argiles de Sheppy. Les Teuthies par contre, cette famille essentiellement méridionale, qui ne se trouve que dans les mers du Sud, et qui n'a aucun représentant dans la faune actuelle de l'Angleterre, ne compte pas moins de trois genres dans la faune de Sheppy, d'où il faut conclure que cette faune doit avoir vécu dans des conditions climactériques différentes de celles des côtes actuelles de l'Angleterre. Ce fait, qui est d'une haute importance pour toute la géologie, se confirme aussi par l'étude des autres groupes de la classe des poissons.

Les Cycloïdes acanthoptérygiens comptent 10 familles dans la faune vivante de l'Angleterre. La faune de Sheppy en compte six, en y comprenant un poisson encore quelque peu douteux voisin des Athérines. Il n'y a que les Lophioïdes et les Tænioïdes, les Trachinides, les Discoboles et les Echénéides, toutes familles peu nombreuses de nos jours, qui n'auraient pas existé dans l'époque tertiaire en Angleterre. Les Sphyrènes, qui appartiennent surtout aux mers tropicales, et qui ne se trouvent pas maintenant sur les côtes de l'Angleterre, sont représentés par un genre très voisin de la Sphyrène commune, et les Xiphioïdes qui habitent de préférence les parages des pays chauds ne comptent pas moins de 4 genres à Sheppy. La seule espèce qui se pèche quelquefois sur les côtes de l'Angleterre, savoir l'espadon commun (Xiphias gladius), n'y est qu'en passage; sa véritable patrie est la Méditerranée. Les Xiphioïdes de Sheppy ont tous le bec arrondi comme le Tetrapture et les Histiophores; or ces derniers ne quittent jamais les mers du Sud. On ne peut rien conclure des Labroïdes, qui sont à peu près dans la même proportion dans la faune d'Angleterre que dans celles des mers du Sud; il est pourtant digne de remarque que le seul Labroïde que j'aie trouvé jusqu'ici à Sheppy, se rapproche d'avantage des vrais Labres, qui habitent encore

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fish, for instance the *Pleuronectidæ*, the *Cottoidæ* and *Gobioidæ*, are altogether absent from the Sheppey clays. The *Teuthiæ*, on the contrary, a family essentially meridional, which only occurs in the Southern seas, and which has no representative in the present fauna of England, is represented by no less than 3 genera in the Sheppey fauna, whence it must be concluded that this fauna existed under conditions of climate very different from those of the present coasts of England. This fact, which is of considerable importance for geology, is likewise confirmed by the study of other groups of fish.

The Acanthopterygian *Cycloidæ* count 10 families in the present fauna of England, that of Sheppey comprises 6, including a fish still somewhat doubtful, but which comes near to the *Atherinæ*. Only the *Lophioidæ* and *Tænioidæ*, the *Trachinoidæ*, the *Discoboli*, and the *Echeneidæ*, all small families, at the present day appear not to have existed in the tertiary epoch of England. The *Sphyrenæ*, which belong especially to tropical seas, and which do not occur at present on the coasts of England, are represented by a genus nearly related to the common *Sphyrena*, and the *Xiphioidæ*, which inhabit, by preference, the coasts of hot countries, have not less than 4 genera at Sheppey. The only species which is sometimes taken on the coast of England, namely the common Espadon, *Xiphias gladius*, is merely on its passage, its true habitat being the Mediterranean. The *Xiphioides* of Sheppey have all a rounded beak like *Tetrapturus* and the *Histiophori*; now these latter never quit the Southern seas. No conclusion can be drawn from the *Labroidæ*, which are nearly in the same proportion in the English fauna as in those of the Southern seas; it is however worthy of remark, that the only Labroid which I have hitherto found at Sheppey, more nearly approaches to the true *Labri* which maintenant ces parages, que des formes que l'on trouve dans les mers du Sud.

Les Cycloïdes malacoptérygiens enfin comptent 5 familles dans l'argile de Sheppy, et le même nombre dans les mers d'Angleterre, mais ce ne sont pas exactement les mêmes. La famille qui fait défaut dans le terrain tertiaire est celle des Salmonides. En revanche une famille essentiellement méridionale, celle des Characins, qui n'existe pas dans les parages Anglais, est représentée dans l'argile de Londres par une, et peut être par deux espèces, de taille très considérable. C'est à Sheppy que j'ai découvert les premiers Gadoïdes fossiles connus, et ce fait est d'autant plus curieux que la famille des Gadoïdes appartient presque exclusivement aux mers froides, et ne compte que fort peu de représentans dans les mers chaudes et tempérées de l'époque actuelle. Il a fort-bien pu en être autrement aux époques tertiaires; car les argiles de Sheppy sont le premier dépôt septentrional marin de formation récente dont on ait examiné les poissons. Les dépôts d'Œningen sont des terrains d'eau douce et ne contiennent aucun Gadoïdes; les schistes de Monte-Bolca n'en récèlent pas non plus, et en ceci ils se montrent d'accord avec le caractère essentiellement tropical de leur faune. Les Gadoïdes avec leurs nombreuses espèces si utiles à l'homme sont encore maintenant les habitans des mers du Nord; la faune d'Angleterre en possède un grand nombre, et il n'est pas sans intérêt de retrouver dans ces mêmes lieux les premiers représentans d'une famille, que je croyais jusqu'ici exclusivement récente. Ce fait joint à celui de la nature du Labre fossile que je viens de mentionner, prouve que, nonobstant la physionomie plus méridionale du dépôt de Sheppy dans son ensemble, il y a pourtant déjà dans les poissons de cette intéressante localité un acheminement vèrs le caractère actuel de la faune ichthyologique d'Angleterre.

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still inhabit those coasts than the forms which are met with in the Southern seas.

The Malacopterygian *Cycloidæ* comprehend 5 families in the Sheppey clay, and the same number in the British seas, but they are not exactly the same. The family which is wanting in the tertiary deposit is that of the *Salmonidæ*. On the other hand, a family totally meridional, that of the *Characidæ*, which does not exist on the English shores, is represented in the London clay by one or perhaps two species of very considerable size. It was at Sheppey that I discovered the first known fossil Gadoid, and this fact is the more curious as the family belongs almost exclusively to the Northern seas, and has very few representatives in the hot and temperate seas of the present period. It was probably different during the tertiary epochs, for the Sheppey clays are the first septentrional marine deposit of recent formation of which the fish have been examined. The deposits of Oeningen consist of freshwater beds, and do not contain any of the *Gadoidæ*, nor do any occur in the schists of Monte Bolca, and in this they agree with the essentially tropical character of their fauna. The *Gadoidæ*, with their numerous species so useful to man, are at present still inhabitants of the Northern seas; the fauna of England possesses a large number, and it is not without interest to find in these same localities the first representatives of a family which I hitherto believed to be exclusively recent. This fact, added to that relating to the nature of the fossil *Labrus* above-mentioned, proves that notwithstanding the more meridional physiognomy of the Sheppey deposit as a whole, there is nevertheless already an approximation in the fish of this interesting locality towards the actual character of the ichthyological fauna of England.

Quant à la détermination générique de ces fossiles, je n'ai pu faire rentrer que fort peu d'espèces de Sheppy dans les genres vivans. Il n'y a que 4 genres, les Megalops, Cybium, Tetrapterus et Myripristis, dont on connait encore des représentans dans la création actuelle. Mais on chercherait en vain des espèces de ces genres dans la faune actuelle des mers d'Angleterre; c'est dans les mers plus méridionales, que se trouvent les espèces qui se rapprochent de celles qui ont vécu en Angleterre pendant l'époque tertiaire.

En me voyant ainsi contraint d'éloigner des genres de notre époque un grand nombre de poissons des temps tertiaires, j'ai conçu quelques doutes sur la détermination générique de plusieurs poissons de Monte-Bolca que j'ai rapportés à des genres vivans. Il importera de les revoir, en tenant compte des moindres différences qu'ils présentent, pour s'assurer si, comme la faune ichthyologique de Sheppy, celle de Monte-Bolca ne renferme pas un nombre de types génériques éteints plus considérable qu'on ne l'a cru jusqu'ici.

Pour completer cet aperçu je joins ici la liste des poissons fossiles de Sheppy que je suis parvenu à déterminer jusqu'ici.

Les espèces déjà mentionnées dans mes Recherches sont marquées d'un astérisque, mème celles qui ne sont que simplement indiquées, sans être décrites.

CTÉNOÏDES.

Percoïdes.

Myripristis toliapicus.
Cœloperca latifrons.
Eurygnathus cavifrons.
*Podocephalus nitidus.
Synophrys Hopei.
*Brachygnathus tenuiceps.
Percostoma angustum.

Sparoïdes.

*Sciænurus Bowerbanki.
*Sciænurus crassior.

Teuthies.

Ptychocephalus radiatus.
Pomaphractus Egertoni.
Calopomus porosus?

CYCLOÏDES ACANTHOPTÉRYGIENS.

Scombéroïdes.

*Cybium macropomum.
*Cœlopoma Colei.
*Cœlopoma læve.
*Bothrosteus latus.
*Bothrosteus brevifrons.
Bothrosteus minor.

With respect to the generic determination of these fossils, I have been able to reduce but very few species from Sheppey to living genera. There are but 4 genera, *Megalops*, *Cybium*, *Tetrapterus* and *Myripristis*, representatives of which are still known in the present creation. But we should look in vain for species of those genera in the present fauna of the English seas; it is only in the more southern seas that species occur approaching to those which lived in England during the tertiary epoch. Finding myself obliged to remove a vast number of fish of the tertiary period from genera now existing, I have some doubts as to the generic determination of several fish from Monte Bolca which I had referred to recent genera. It will be important to re-examine them, taking into account the smallest differences they present, in order to ascertain whether, like the ichthyological fauna of Sheppey, that of Monte Bolca does not contain a number of extinct generic types far more considerable than hitherto supposed. To render this sketch complete, I here add the list of the fossil fish of Sheppey which I have hitherto succeeded in determining.

The species already mentioned in my 'Recherches' are marked with an asterisk, even those which have been simply indicated without being described. [See table supra.]

Phalacrus cybioïdes.
Rhonchus carangoides.
Echenus politus.
Scombrinus nuchalis.
*Cœlocephalus salmoneus†.
Naupygus Bucklandi†.

Xiphioïdes.

*Tetrapterus priscus.
*Cœlorhynchus rectus.
*Cœlorhynchus sinuatus.
Phasganus declivis.
Acestrus ornatus.

Sphyrænoïdes.

*Sphyrænodus priscus.
*Sphyrænodus crassidens.

Labroïdes.

Auchenilabrus frontalis.

Blennioïdes.

Laparus alticeps.

Cycloïdes Malacoptérygiens.

Scomberésoces.

*Hypsodon toliapicus.
*Hypsodon oblongus.
Labrophagus esocinus.

Clupéides.

*Halecopsis lævis.
*Megalops priscus.

Characins.

Brychetus Mülleri.

Gadoïdes.

*Rhinocephalus planiceps.
Merlinus cristatus.
*Ampheristus toliapicus.
*Goniognathus coryphænoides.

Anguilliformes.

Rhynchorhinus branchialis.

Famille douteuse.

*Pachycephalus cristatus.
Rhipidolepis elegans.
*Glyptocephalus radiatus.
Gadopsis breviceps.
Loxostomus mancus.

Ganoïdes‡ (Types anciens).

Pycnodontes.

*Pycnodus toliapicus.
*Periodus Kœnigii.
*Gyrodus lævior.
*Phyllodus toliapicus.
*Phyllodus planus.
*Phyllodus polyodus.
*Phyllodus marginalis.
*Phyllodus irregularis.
*Phyllodus medius.
*Pisodus Owenii.

Acipenserides.

*Acipenser toliapicus.

Placoïdes.

Rayes.

*Myliobates Owenii.
*Myliobates acutus.
*Myliobates canaliculatus.
*Myliobates lateralis.
*Myliobates marginalis.
*Myliobates toliapicus.
*Myliobates goniopleurus.
*Myliobates Dixoni.
*Myliobates striatus.
*Myliobates punctatus.
*Myliobates gyratus.
*Myliobates jugalis.
*Myliobates nitidus.
*Myliobates Colei.
*Myliobates heteropleurus.
*Aetobatis irregularis.
*Aetobatis subarcuatus.
*Pristis bisulcatus.
*Pristis Hastingsiæ.

Squalides.

*Notidanus serratissimus.
*Glyphis hastalis.
*Carcharodon toliapicus.
*Carcharodon subserratus.
*Otodus obliquus.
*Otodus macrotus.
*Lamna elegans.
*Lamna compressa.
*Lamna (Odontaspis) Hopei.
*Lamna (Odontaspis) verticalis.

Chimérides.

*Elasmodus Hunterii.
*Psaliodus compressus.
*Edaphodon eurygnathus.

† J'ai quelque doutes sur la position systématique de ces deux poissons.

‡ Si je n'ai rien dit des familles suivantes dans ce rapport, c'est que je n'ai, pour le moment, rien à ajouter de nouveau à ce que j'ai publié à leur sujet, dans mes *Recherches*.

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† I have some doubts as to the systematic position of these two fish.

‡ If I have made no mention of the following families in this report, it is that I have nothing new at the present moment to add to what I have already published on them in my 'Recherches.'

On voit par là que le nombre des poissons fossiles de l'argile de Londres s'élève à 92, dans la seule localité de Sheppy, sans compter une dixaine d'espèces auxquelles je n'ai pas encore donné de noms, n'ayant pas encore pu les caractériser d'une manière suffisante.

Il ne sera peut-être pas inutile d'ajouter à ce rapport le liste des crânes et des squelettes de poissons vivans que j'ai réunis pour l'étude des poissons fossiles de Sheppy. Les géologues et les anatomistes jugeront par là du degré de confiance que mérite ce travail, et ils verront en même temps ce qu'il y a encore à faire dans ce domaine aussi vaste que neuf. J'espère du reste augmenter de jour en jour cette collection dans la mesure de mes forces, de même que j'ai la confiance que les géologues Anglais voudront bien continuer à me faire part des nouvelles acquisitions qu'ils feront dans la faune ichthyologique de l'argile de Londres. Je ne serais pas moins reconnaissant envers les zoologistes qui voudraient contribuer à l'avancement de mon travail, en m'envoyant des squelettes ou des têtes de poissons préparées, ou même simplement des poissons conservés dans l'esprit de vin propres à augmenter ma collection de squelettes et de crânes.

CTÉNOÏDES.

Percoïdes.

Labrax Lupus.
Centropomus undecimalis.
Apogon Rex Mullorum.
Capros aper.
Priacanthus macrophthalmus.
Anthias sacer.
Serranus Scriba.
Serranus Cabrilla.
Mullus barbatus.

Sparoïdes.

Sargus annularis.
Sargus Salviani.
Charax Puntazza.
Chrysophrys microdon.
Pagellus erythrinus.
Pagellus mormyrus.
Pagellus centrodontus.
Boops Salpa.
Boops vulgaris.
Dentex vulgaris.
Mæna vulgaris.
Mæna Osbecki.
Smaris insidiator.

Sciænoïdes.

Hæmulon lanna.
Ancylodon jaculidens.
Otolithus turu.
Corvina nigra.

Chromides.

Cychla labrina.

From this it will be seen that the number of fossil fish from the London clay amounts to 92 in the one single locality of Sheppey, without counting 10 species to which I have not yet assigned names, not having hitherto been able to characterize them in a satisfactory manner.

It will perhaps not be useless to add to this report the list of the crania and skeletons of recent fish which I have collected for the study of the fossil fish of Sheppey. It will enable geologists and anatomists to judge of the degree of confidence which this investigation merits; and they will see at the same time what still remains to be accomplished in this vast and new field of research. I hope to increase this collection daily in proportion to my means, and I am confident that English geologists will still kindly continue to communicate to me the new acquisitions they may make in the ichthyological fauna of the London clay. I shall not be less grateful towards those zoologists who would contribute to the advancement of my researches by forwarding me skeletons or heads of prepared fish, or simply fish preserved in spirits adapted to increase my collection of skeletons and crania.

Pomacentrides.

Heliases Chromis.
Amphiprion tunicatus.

Cottoïdes.

Dactylopterus volitans.
Trigla adriatica.
Trigla Lyra.
Trigla Hirundo.
Platycephalus insidiator.
Scorpæna Scrofa.
Synauceya Brachio.

Mugiloïdes.

Mugil cephalus.

Gobioïdes.

Gobius niger.
Gobius auratus.
Gobius jozzo.

Teuthies.

Acanthurus Chirurgus.
Naseus Beselii.
Amphacanthus Bahal.

Aulostomes.

Centriscus Scolopax.

Chétodontes.

Chætodon vagabundus.
Pomacanthus 5-cinctus.
Ephippus faber.

Pleuronectes.

Rhombus lævis.

CYCLOÏDES.

a. ACANTHOPTÉRYGIENS.

Scombéroïdes.

Scomber Scomber.
Centrolophus pompilius.
Lepidopus Peroni.
Caranx trachurus.
Zeus Faber.
Zeus pungia.

Xiphioïdes.

Xiphias Gladius.
Tetrapterus Belone.

Sphyrænoïdes.

Sphyræna Spet.

Tænioïdes.

Cepola Tænia.
Gymnetrus Iris.

Trachinides.

Trachinus lineatus.
Trachinus Draco.
Uranoscopus scaber.

Athérinoïdes.

Atherina Hepsetus.
Atherina Humboldtii.

Labroïdes.

Labrus viridis.
Labrus carneus.
Crenilabrus Norwegicus.
Crenilabrus melops.
Crenilabrus Pavo.
Coricus Lamarckii.
Iulis Giofredi.
Xyrichthys Novacula.

Blennioïdes.

Blennius ocellaris.
Blennius Gattorugine.
Anarrhichas Lupus.

Lophioïdes.

Lophius piscatorius.
Batrachus Surinamensis.

b. MALACOPTÉRYGIENS.

Scomberésoces.

Belone longirostris.
Hemiramphus Brasiliensis.
Exocœtus evolans.

Clupéides.

Alosa vulgaris.
Alosa Finta.
Clupea sprattus.
Engraulis encrasicholus.

Scopélines.

Saurus fœtens.

Salmones.

Osmerus Eperlanus.

Anguilliformes.

Conger vulgaris.
Muræna Helena.
Ophisurus Serpens.

Ophidioïdes.

Ophidium barbatum.

Gadoïdes.

Merlangus vulgaris.
Gadus minutus.
Motella fusca.
Merlucius vulgaris.
Phycis Tinca.

Echénéides.

Echeneis nemora.

Report on Waves. *By* J. Scott Russell, *Esq., M.A., F.R.S. Edin., made to the Meetings in* 1842 *and* 1843.

Members of Committee { Sir John Robison*, *Sec. R.S. Edin.*
J. Scott Russell, *F.R.S. Edin.*

A Provisional Report on this subject was presented to the Meeting held at Liverpool in 1838, and is printed in the Sixth Volume of the Transactions. That report was a partial one. It states that "the extent and multifarious nature of the subjects of inquiry have rendered it impossible to terminate the examination of all of them in so short a time; but it is their duty to report the progress which they have made, and the partial results they have already obtained, leaving to the reports of future years such portions of the inquiries as they have not yet undertaken."

The first of these subjects of inquiry is stated to have been "to determine the varieties, phænomena and laws of waves, and the conditions which affect their genesis and propagation."

It is this branch of the duty of the Committee which forms the subject of the present report. Ever since the date of that report, it has happened that the author of this has been so fully pre-occupied by inevitable duty, that it was not in his power to indulge much in the pleasures of scientific inquiry; and as the active part of the investigation necessarily devolved upon him, it was not practicable to continue the series of researches on the ample and systematic scale originally designed, so soon as he had anticipated, so that the former report has necessarily been left in a fragmentary state till now.

But I have never ceased to avail myself of such opportunities as I could contrive to apply to the furtherance of this interesting investigation. I have now fully discussed the experiments which the former report only registered. I have repeated the former experiments where their value seemed doubtful, I have supplemented them in those places where examples were wanting. I have extended them to higher ranges, and where necessary to a much larger scale. In so far as the experiments have been repeated and more fully discussed, they have tended to confirm the conclusions given in the former report, as well as to extend their application.

The results here alluded to are those which concern especially the velocity and characteristic properties of the solitary wave, that class of wave which the writer has called the great wave of translation, and which he regards as the primary wave of the first order. The former experiments related chiefly to the mode of genesis, and velocity of propagation of this wave. They led to this expression for the velocity in all circumstances,

$$v = \sqrt{g(h+k)},$$

k being the height of the crest of the wave above the plane of repose of the fluid, h the depth throughout the fluid in repose, and g the measure of gravity. Later discussions of the experiments not only confirm this result, but are themselves established by such further experiments as have been recently instituted, so that this formerly obtained velocity may now be regarded as the phænomenon characteristic of the wave of the first order.

The former series of experiments also contained several points of research not published in the former report, because not sufficiently extended to be of

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* I cannot allow these pages to leave my hands without expressing my deep regret that the death of Sir John Robison has suddenly deprived the Association of a zealous and distinguished office-bearer, and myself of a kind friend. In all these researches the responsible duties were mine, and I alone am accountable for them; but in forwarding the objects of the investigation I always found him a valuable counsellor and a respected and cordial cooperator.

the desired value. Among these were a series of observations on the actual motion of translation of particles of the fluid during wave transmission; these have since been completed and extended, and the results of the whole are now given.

The former report was inevitably a fragment. I have endeavoured to give to the present report a somewhat greater degree of completeness. For this purpose I have now incorporated under one general form all those results of the present as well as of all my former researches, which could contribute to the unity and completeness of the view of a subject so interesting and important. I have re-discussed my former experiments, combined them with the more recent observations, and thus, from a wider basis of induction, obtained results of greater generality. Until the date of these observations, there had been confounded together in an indefinite notion of waves and wave motion, phænomena essentially different,—different in their genesis, laws of propagation, and other characteristics. I have endeavoured, by a rigid course of examination, to distinguish these different classes of phænomena from each other. I have determined certain tests, by which these confused phænomena have been made to divide themselves into certain classes, distinguished by certain great characteristics. Contradictions and anomalies have in this process gradually disappeared; and I now find that all the waves which I have observed may be distinguished into four great orders, and that the waves of each order differ essentially from each other in the circumstances of their origin, are transmitted by different forces, exist in different conditions, and are governed by different laws. It is now therefore easy to understand how much has been hitherto added to the difficulty of this difficult subject, by confounding together phænomena so different. The characteristics, phænomena, and laws of these great orders I have attempted in the present report to determine and define.

The knowledge I have thus endeavoured to obtain and herein to set forth concerning these beautiful and interesting wave phænomena, is designed to form a contribution to the advancement of hydrodynamics, a branch of physical science hitherto much in arrear. But besides this their immediate design, these investigations of wave motion are fertile in important applications, not only to illustrate and extend other departments of science, but to subserve the purposes and uses of the practical arts. I have ascertained that what I have called the great wave of translation, my wave of the first order, furnishes a type of that great oceanic wave which twice a day brings to our shores the waters of the tide. This type enabled us to understand and explain by analogy many of the phænomena of fluvial and littoral *tides*, formerly anomalous (see Proceedings R.S. Ed., 1838); and thus do these wave researches contribute to the advancement of the theory of the tides, a branch of physical astronomy long stationary, but which has recently made rapid strides towards the same high perfection which other branches of predictive astronomy have long enjoyed, a perfection which we owe chiefly to Sir John W. Lubbock, to Mr. Whewell, and the co-operation of the British Association. It is the wave of the first order enumerated in this report which furnishes to us the model of a terrestrial mechanism, by means of which the forces primarily imparted by the sun and moon are taken up and employed in the transport of tidal waters to distant shores (see previous Reports of Brit. Ass.), and their distribution in remote seas and rivers, which they continue in succession to agitate long after the forces employed in the genesis of the wave have ceased to exist (see Report on Tides). This application of the phænomena of waves to explain the tides is not their only application to the advancement of other branches of science. The phænomena of *resistance of fluids* I have found to be intimately connected with those waves (see Phil. Trans. Edin.

1837). The resistance which the water in a channel opposes to the passage of a floating body along that channel depends materially on the nature of the great wave of the first order, which the floating body generates by the force which propels it, and its motion is materially affected by the genesis of waves also, of the second order, arising from the same cause. These waves are therefore important elements in the resistance of fluids, and acquaintance with their phænomena is essential to the sound determination and explanation of the motion of floating bodies. If to these two branches of science we add the useful arts, in which an accurate acquaintance with wave phænomena may be of practical value to the purposes of human life, we shall find that the improvement of *tidal rivers*, the construction of *public works* exposed to the action of waves and of tides, and the *formation of ships* (see Reports of Brit. Ass. *passim*), are among the most direct and necessary applications of this knowledge, which is indeed essential to the just understanding of the best methods of opposing the violence of waves, and converting their motion to our own uses. By a careful study of the laws and phænomena of waves, we are enabled to convert these dangerous enemies into powerful slaves. By such applications of our wave researches, we therefore extend our knowledge in conformity with the maxims of the illustrious founder of our inductive philosophy, who enjoins that we always study to combine with our *experimenta lucifera* such *experimenta fructifera*, that while science is advanced society may be advantaged.

The Nature of Waves and their Variety.

When the surface of water is agitated by a storm, it is difficult to recognize in its tumultuous tossings, any semblance of order, law, or definite form, which the mind can embrace so as adequately to conceive and understand. Yet in all the madness of the wildest sea the careful observer may find some traces of method; amid the chaos of water he will observe some moving forms which he can group or individualize; he may distinguish some which are round and long, others that are high and sharp; he may observe those that are high gradually becoming acuminate and breaking with a foaming crest, and may notice that the motion of those which are small is short and quick, while the rising and falling of large elevations is long and slow. Some of the crests will advance with a great, others with a less velocity; and in all he will recognize a general form familiar to his mind as the form of the sea in agitation, and which at once distinguishes it from all other phænomena.

Just as the waters of a reservoir or lake when in perfect repose are characterized by a smooth and horizontal surface, so also does a condition of disturbance and agitation give to the surface of the fluid this form characteristic of that condition and which we may term the wave form. When any limited portion of the wave surface presents a defined figure or boundary, which appears to distinguish that portion of fluid visibly from the surrounding mass, our mind gives it individuality,—we call it *a wave*.

It is not easy to give a perfect definition of a wave, nor clearly to explain its nature so as to convey an accurate or sufficiently general conception of it. Persons who are placed for the first time on a stormy sea, have expressed to me their surprise to find that their ship, at one moment in the trough between two waves, with every appearance of instant destruction from the huge heap of waters rolling over it, was in the next moment riding in safety on the top of the billow. They discover with wonder that the large waves which they see rushing along with a velocity of many miles an hour, do not carry the floating body along with them, but seem to pass under the bottom of the ship without injuring it, and indeed with scarcely a perceptible effect in carrying the vessel out of its course. In like manner the observer near the shore perceives that pieces of wood, or any floating bodies immersed in the water near its surface, and the water in their vicinity, are not carried towards the shore with the rapidity of the wave, but are left nearly in the same place after the wave has passed them, as before. Nay, if the tide be ebbing, the waves may even be observed coming with considerable velocity towards the shore, while the body of water is actually receding, and any object floating in it is carried in the opposite direction to the waves, out to sea. Thus it is that we are impressed with the idea, that *the motion of a wave may be different from the motion of the water* in which it moves; that the water may move in one direction and the wave in another; that water may transmit a wave while itself may remain in the same place.

If then we have learned that a water wave *is not* what it seems, a heap of water moving along the surface of the sea with a velocity visible to the eye, it is natural to inquire what a wave really is; *what is wave-motion as distinct from water-motion?*

For the purpose of this inquiry let us take a simple example. I have a long narrow trough or channel of water, filled to the depth of my finger length. I place my hand in the water, and for a second of time push forward along the channel the water which my hand touches, and instantly cease from further motion. The immediate result is easily conceived; I have simply pushed forward the particles of water which I touched, out of their former place to another place further on in the channel, and they repose in their new place at rest as at first. Here is a final effect, and here my agency has ceased —not so the motion of the water; I pushed forward a given mass out of its place into another, but that other place was formerly occupied by a mass of water equal to that which I have forcibly intruded into its place; what then has become of the displaced occupant? it has been forced into the place of that immediately before it, and the occupant which it has dislodged is again pushed forward on the occupant of the next place, and thus in succession volume after volume continues to carry on a process of displacement which only ends with the termination of the channel, or with the exhaustion of the displacing force originally impressed by my hand, and communicated from one to another successive mass of the water. This process continues without the continuance of the original disturbing agency, and is prolonged often to great distances and through long periods of time. The continuation of this motion is therefore independent of the volition which caused it. It is a process carried on by the particles of water themselves obeying two forces, the original force of disturbance and the force of gravity. It is therefore a hydrodynamical phænomenon conformable to fixed law. I have now ceased to exercise any control over the phænomenon, but as I attentively watch the processes I have set a-going, I observe each successive portion of water in the act of being displaced by one moving mass of water, and in the act of displacing its successor. As the water particles crowd upon one another in the act of going out of their old places into the new, the crowd forms a temporary heap visible on the surface of the fluid, and as each successive mass is displacing its successor, there is always one such heap, and this heap travels apparently along the channel at that point where the process of displacement is going on, and although there may be only one crowd, yet it consists successively of always another and another set of migrating particles.

This *visible moving heap of crowding particles* is a true *wave*, the rapidity with which the displacement of one outgoing mass by that which takes its place, goes forward, determines the velocity with which the heap appears to move, and is called the *velocity of transmission* of the wave. The shape which the crowding of the particles gives to the surface of the water constitutes the *form of the wave.* The distance (in the direction of the transmission) along which the crowd extends, is called the *length or amplitude* of the wave. The number of particles which at any one time are out of their place, constitute the *volume of the wave*; the time which must elapse before particles can effect their translation from their old places to the new, may be termed the *period of the wave.* The *height of the wave* is to be reckoned from the highest point or crest to the surface of the fluid when in repose.

Such is the wave motion—very different is the *water motion.* Let us select from the crowd of water particles an individual and watch its behaviour during the migration. The progressive agitation first reaches it while still in perfect repose; the crowd behind it push it forward and new particles take its place. One particle is urged forward on that before it, and being still urged on from behind by the crowd still swelling and increasing, it is *raised* out of its place and *carried forward* with the velocity of the surrounding particles; it is urged still on until the particles which displaced it have made room for themselves behind it, and then the power diminishes. Having now in its turn pushed the particles before it along out of their place, and crowded them together on their antecedents, it is gradually left behind and finally *settles quietly down in its new place.* Thus then the *motion of migration of an individual particle* of water is very different from the *motion of transmission of the wave.*

The wave goes still forward along through the channel, but each individual water particle remains behind. The wave passes on with a continuous uninterrupted motion. The water particle is at rest, starts, rises, is accelerated, is slowly retarded, and finally stops still. The *range of the particle's motion* is short; its *translation* is interrupted and final. Its *vertical range* and *horizontal range are finite.* It describes an *orbit* or path during the *transit of the wave* over it, and remains for ever after at rest, unless when a second wave happens immediately to follow the first, when it will describe a second time *its path of translation,* passing through a series of new positions or *phases* during the *period of the wave.* The motion of the particle is not therefore like the apparent motion of the wave, either uniform or continuous. The motion of the water particles is a true motion of translation of matter from one place to another, with the velocity and range which the senses observe. But the wave motion is an ideal individuality attributed by the mind of the observer to a process of changes of relative position or of absolute place, which at no two instants belongs to the same particles in the same place. The water does not travel, the visible heap at no two successive instants is the same. It is the motion of particles which goes on, now at this place, now at that, having passed all the intermediate points. *It is the crowding motion alone which is transmitted.* This crowding motion transmitted along the water idealised and individualised is a true wave.

Wave propagation therefore consists in the transmission from one class of particles to another, of a motion differing in kind from the motion of transmission. *Wave motion* is therefore transcendental motion; motion in the second degree; the motion of motion—the transference of motion without the transference of the matter, of form without the substance, of force without the agent.

It is essential to the accurate conception and examination of waves, that this *distinction between the wave motion and the water motion* be clearly conceived. It has been well illustrated by the agitations of a crowd of people, and of a field of standing corn waving with the wind. If we stand on an eminence, we notice that each gust as it passes along the field bending and crowding the stalks, marks its course by the motion it gives to the grain, and the visible effect is like that of an agitated sea. The waving motion visibly travels across the whole length of the field, but the corn remains rooted to the ground; this illustration is as apt as old, being given to us in the Iliad, at the conclusion of the speech of Agamemnon, beginning Ὦ φίλοι, ἥρωες Δαναοί.

> Ὣς φάτο· . . . .
> Κινήθη δ' ἀγορὴ, ὡς κύματα μακρὰ θαλάσσης
> Πόντου Ἰκαρίοιο, τὰ μέν τ' Εὖρός τε Νότος τε
> Ὤρορ', ἐπαΐξας πατρὸς Διὸς ἐκ νεφελάων.
> Ὡς δ' ὅτε κινήσει Ζέφυρος βαθὺ λήϊον, ἐλθὼν
> Λάβρος, ἐπαιγίζων, ἐπί τ' ἠμύει ἀσταχύεσσιν·
> Ὣς τῶν πᾶσ' ἀγορὴ κινήθη.—Il. II. 144–149.

In the examination of the phænomena of waves, we have therefore two classes of elements for consideration, the elements of the wave motion and the elements of the water particle motion. We may first examine the *phænomena of a given wave-motion*, its range of transmission over the surface of the fluid, the velocity of that transmission, the form of the elevation, its amplitude, breadth, height, volume, period. We may next consider the *path which each water particle describes* during the wave transit; the *form* of that path, the *horizontal or vertical range* of the motion, the variation of the path with the depth, the relation of each *phase of the particle's orbit* to each portion of the corresponding wave length. By this examination I have found that there exist among waves groups of phænomena so different as to suggest their division into *distinct classes.* I find that the general form of waves is manifestly different, one kind of wave making its appearance in a form always wholly raised above the general surface of the fluid, and which we may call a *positive wave,* and so distinguish it from another form of wave which is wholly *negative,* or depressed below the plane of repose, while a third class are found to consist of both a negative and a positive portion. I find them propagated with extremely different velocities, and obeying different laws according as they belong to one or the other of these classes, the positive wave having *in a given depth of water a constant and invariable velocity,* while another class has a *velocity varying* according to other peculiarities, and *independent of the depth.* Some of them again are distinguished by always appearing alone as individual waves, and others as *companion phænomena* or *gregarious,* never appearing except in groups. In examining the paths of the water particles corresponding differences are observed. In some the water particles perform a *motion of translation* from one place to another, and effect a permanent and final change of place, while others merely change their place for an instant to resume it again; thus performing *oscillations* round their place of final repose. These waves may also be distinguished by the sources from which they arise, and the forces by which they are transmitted. One class of wave is a *motion of successive transference* of the whole fluid mass; a second, the *partial oscillation* of one part of it without affecting the remainder; a third, the propagation of an impulse by the *corpuscular forces* which determine the elasticity of the fluid mass; and a fourth, by the *capillary forces* uniting its molecules at the surface.

These classes, so various both in their origin, cause and phænomena, have not hitherto been sufficiently distinguished, but have either been unknown, or have been confounded with each other under the vague conception and general designation of wave motions. The following table is given as a *first approximation towards a classification of the phænomena of wave motion.* It comprehends all the waves which I have investigated, and sufficiently distinguishes them from each other. I find that water waves may be distributed into *four orders.* The *wave of translation* is the wave of the FIRST ORDER, and consists in a motion of translation of the whole mass of the fluid from one place to another, to another in which it finally reposes; its aspect is, a *solitary* elevation or a solitary hollow or cavity, moving along the surface with a *uniform* velocity; and hence it presents two species, *positive and negative,* and each of these may be found in a condition of *free* motion, or affected in form and velocity by the continual interference of a *force* of the same nature with that from which its genesis was derived. The wave of the SECOND ORDER is partly positive and partly negative, *each height having a companion hollow,* and this is the commonest order of visible water wave, being similar to the usual *wind waves,* in which the surface of the water visibly *oscillates* above and below the level of repose; these waves appear in *groups*; in some cases, as in running water, they may be *standing* elevations and depressions, and in others *progressive* along the surface, and like the waves of the first order, may be altered in form and velocity by the presence of a disturbing force, so as to differ from their phænomena when in a state of perfect freedom. The THIRD CLASS are met with under such conditions as agitate the fluid only to a very minute depth, and are determined by the same forces which in hydrostatics produce the phænomena of *capillary attraction*; and the FOURTH ORDER is that wave insensible to sight, which conveys the disturbance produced by a sonorous body through a mass of the fluid, and which is at once an index and a result of the molecular forces which determine the elasticity of the fluid. This classification has been adopted throughout the following paper.

TABLE I.

System of Water Waves.

ORDERS.	FIRST.	SECOND.	THIRD.	FOURTH.
Designation.	Wave of translation.	Oscillating waves.	Capillary waves.	Corpuscular wave.
Characters...	Solitary.	Gregarious.	Gregarious.	Solitary.
Species ...	Positive. Negative.	Stationary. Progressive.	Free. Forced.	
Varieties	Free. Forced.	Free. Forced.		
Instances	The wave of resistance. The tide wave. The aërial sound wave.	Stream ripple. Wind waves. Ocean swell.	Dentate waves. Zephyral waves.	Water-sound wave.

An observer of natural phænomena who will study the surface of a sea or large lake during the successive stages of an increasing wind, from a calm to a storm, will find in the whole motions of the surface of the fluid, appearances which illustrate the nature of the various classes of waves contained in Table I., and which exhibit the laws to which these waves are subject. Let him begin his observations in a perfect calm, when the surface of the water is smooth and reflects like a mirror the images of surrounding objects. This appearance will not be affected by even a slight motion of the air, and a velocity of less than half a mile an hour ($8\frac{1}{2}$ in. per sec.) does not sensibly disturb the smoothness of the reflecting surface. A gentle zephyr flitting along the surface from point to point, may be observed to destroy the perfection of the mirror for a moment, and on departing, the surface remains polished as before; if the air have a velocity of about a mile an hour, the surface of the water becomes less capable of distinct reflexion, and on observing it in such a condition, it is to be noticed that the diminution of this reflecting power is owing to the presence of those minute corrugations of the superficial film which form waves of the *third order*. These corrugations produce on the surface of the water an effect very similar to the effect of those panes of glass which we see corrugated for the purpose of destroying their transparency, and these corrugations at once prevent the eye from distinguishing forms at a considerable depth, and diminish the perfection of forms reflected in the water. To fly-fishers this appearance is well known as diminishing the facility with which the fish see their captors. This first stage of disturbance has this distinguishing circumstance, that the phænomena on the surface cease almost simultaneously with the intermission of the disturbing cause, so that a spot which is sheltered from the direct action of the wind remains smooth, the waves of the third order being incapable of travelling spontaneously to any considerable distance, except when under the continued action of the original disturbing force. This condition is the indication of present force, not of that which is past. While it remains it gives that deep blackness to the water which the sailor is accustomed to regard as an index of the presence of wind, and often as the forerunner of more.

The second condition of wave motion is to be observed when the velocity of the wind acting on the smooth water has increased to two miles an hour. Small waves then begin to rise uniformly over the whole surface of the water; these are waves of the second order, and cover the water with considerable regularity. Capillary waves disappear from the ridges of these waves, but are to be found sheltered in the hollows between them, and on the anterior slopes of these waves. The regularity of the distribution of these secondary waves over the surface is remarkable; they begin with about an inch of amplitude, and a couple of inches long; they enlarge as the velocity or duration of the wave increases; by and by conterminal waves unite; the ridges increase, and if the wind increase the waves become cusped, and are regular waves of the *second order*. They continue enlarging their dimensions, and the depth to which they produce the agitation increasing simultaneously with their magnitude, the surface becomes extensively covered with waves of nearly uniform magnitude.

How it is that waves of unequal magnitude should ever be produced may not seem at first sight very obvious, if all parts of the original surface continue equally exposed to an equal wind. But it is to be observed that it rarely occurs that the water is all equally exposed to equal winds. The configuration of the land is alone sufficient to cause local inequalities in the strength of the wind and partial variations of direction. By another cause are local inequalities rapidly produced and exaggerated. The configuration of the shores reflects the waves, some in one direction, some in another, and so deranges their uniformity. The transmission of reflected waves over such as are directly generated by the wind, produces new forms and inequalities, which, exposed to the wind, generate new modifications of its force, and of course, in their turn, give rise to further deviations from the primitive condition of the fluid. There are on the sea frequently three or four series of coexisting waves, each series having a different direction from the other, and the individual waves of each series remaining parallel to one another. Thus do the condition, origin, and relations of the waves which cover the surface of the sea after a considerable time, become more complex than at their first genesis.

It is not until the waves of the sea encounter a shallow shelving coast, that they present any of the phænomena of the wave of the first order (Report of 1838). After breaking on the margin of the shoal, they continue to roll along in the shallow water towards the beach, and becoming transformed into waves of the first order, finally break on the shore.

But the great example of a wave of the *first order*, is that enormous wave of water which rolls along our shores, bringing the elevation of high tide twice a day to our coasts, our harbours, and inland rivers. This great compound wave of the first order is not the less real that its length is so great, that while one end touches Aberdeen, the other reaches to the mouth of the Thames and the coast of Holland. Though the magnitude of this wave renders it impossible for the human eye to take in its form and dimensions at one view, we are able, by stationing numerous observers along different parts of the coasts, to compare its dimensions and to trace its progress at different points, and so to represent its phænomena to the eye and the mind on a small scale, as to comprehend its form and nature as clearly as we do those of a mountain range, or extensive country which has been mapped on a sheet of paper by the combination together of trigonometrical processes, performed at different places by various observers, and finally brought together and protracted on one sheet of paper.

As this great wave of the first order is not comprehended by the eye on account of its magnitude, so there is a wave of the *fourth order* which equally escapes detection from that organ, on account of its minuteness. By an undulation propagated among the particles of water, so minute as to be altogether insensible to the eye, and only recognised by an organ appropriate to that purpose, there is conveyed from one place to another the wave of sound. This wave, though invisible from its minuteness, is nevertheless of a nature almost identical with the wave of the first order. In air the sound wave is indeed the wave of the first order. It is only in liquids, when the measure of pressure of the fluid mass is different from the measure of the intercorpuscular force, that the phænomena of the wave of the first order is different from those of the fourth, and that we have one measure for the velocity of the water wave, and another for that of the sound wave. In a gaseous fluid, on the contrary, the measure of the pressure of the mass is also the measure of the intercorpuscular force, and the sound wave becomes identical with the air wave, the fourth order with the first.

SECTION I.—WAVE OF THE FIRST ORDER.

The Wave of Translation.

Character	Solitary.
Species	Positive. Negative.
Varieties	Free. Forced.
Instances	Wave of Resistance. Tidal Wave—Sound Wave.

I believe I shall best introduce this phænomenon by describing the circumstances of my own first acquaintance with it. I was observing the motion of a boat which was rapidly drawn along a narrow channel by a pair of horses, when the boat suddenly stopped—not so the mass of water in the channel which it had put in motion; it accumulated round the prow of the vessel in a state of violent agitation, then suddenly leaving it behind, rolled forward with great velocity, assuming the form of a large solitary elevation, a rounded, smooth and well-defined heap of water, which continued its course along the channel apparently without change of form or diminution of speed. I followed it on horseback, and overtook it still rolling on at a rate of some eight or nine miles an hour, preserving its original figure some thirty feet long and a foot to a foot and a half in height. Its height gradually diminished, and after a chase of one or two miles I lost it in the windings of the channel. Such, in the month of August 1834, was my first chance interview with that singular and beautiful phænomenon which I have called the Wave of Translation, a name which it now very generally bears; which I have since found to be an important element in almost every case of fluid resistance, and ascertained to be the type of that great moving elevation of the sea, which, with the regularity of a planet, ascends our rivers and rolls along our shores.

To study minutely this phænomenon with a view to determine accurately its nature and laws, I have adopted other more convenient modes of producing it than that which I have just described, and have employed various methods of observation. A description of these will probably assist me in conveying just conceptions of the nature of this wave.

Genesis of the Wave of the First Order.—For producing waves of the first order on a small scale, I have found the following method sufficiently convenient. A long narrow channel or box a foot wide, eight or nine inches deep, and twenty or thirty feet long (Plate I. fig. 1.), is filled with water to the height of say four inches. A flat board P (or plate of glass) is provided, which fits the inside of the channel so as to form a division across the channel where it is inserted.

Genesis by Impulsion or Force horizontally applied.—Let this plate be inserted vertically in the water close to the end A, and being held in the vertical position, be pressed forward slowly in the direction of X, care being taken that it is kept vertical and parallel to the end. The water now displaced by the plate P in its new position accumulates on the front of the plane forming a heap, which is kept there, being inclosed between the sides of the channel and the impelling plate. The amount thus heaped up is plainly the volume of water which has been removed by the advancing plane from the space left vacant behind it, and if the impulse increase, the elevation of displaced water will increase in the same quantity. When the water has reached the height P_3, let the velocity of impulsion be now gradually diminished as at P_4, until the plate is finally brought to rest as at P_5; the height of the water heaped on the front will diminish with the diminution of velocity as at P_4, and when brought to rest at P_5 it will be on the original level. The total height of the water does not however subside with the diminution of the impulsion, the crest W_4 retains the maximum height to which it had risen under the pressure of the plane at P_3, and moves horizontally forward; and the smaller elevation produced by the smaller pressure at P_4 down to P_5 moves forward after W_5. This elevation of the liquid, having a *crest*, or summit, or *ridge* in the centre of its length transverse to the side of the channel, continues to move along the channel in the direction of the original impulsion; from the crest there extends forward a curved surface, W*a*, forming the *face* of the *wave*, and a similar surface, W*w*, behind the crest is distinguished as its *back*. It is convenient to designate *a* as the *origin*, *w* as the *end* of the wave; and to designate the interval between *a* and *w*, the length of the wave in the direction of its transmission, its *amplitude*.

The kind of motion required for generating this wave in the most perfect way, that is, for producing a wave of given magnitude without at the same time creating any disturbance of a different kind in the water—this kind of motion may be given by various mechanical contrivances, but I have found that the dexterity of manipulation which experience bestows is perfectly sufficient for ordinary experimental purposes.

Genesis by a Column of Fluid.—This is a method of genesis, of considerable value for various experimental purposes, especially useful when waves of no great magnitude are required, and also when it is desirable to measure accurately volumes or forces employed in wave genesis. The same glass plate may be conveniently employed in this case as in the last, only it will now be used in the capacity merely of a sluice, and be supported by two small vertical slips fixed to the sides of the channel so as to keep it in the vertical position but to admit of its being raised vertically upwards as at G, Pl. XLVII. fig. 2. There is thus formed between the end of the channel G and the moveable plate P_7, a small generating reservoir GP_7. This is to be filled to any desired height with water, as from w to P_7, and the plate being drawn up, as at P_9, the water of the reservoir descends to w, the level of the water of the channel, and pushing forward and heaping up the adjacent fluid, raises a heap equal to the added volume on the surface of the water; and this elevation is in no respect sensibly different either in form or other phænomenon from that generated in the former method, provided the quantity of water added in the latter case be identical with the quantity of water displaced in the former case.

This method of genesis by fluid column affords a simple means of proving an elementary fact in this kind of wave motion. The fact is this, that while the volume of water in the wave is exactly equal to the volume of water added from the reservoir, it is by no means identical with it. I filled the reservoir with water tinged with a pink dye, which did not sensibly alter the specific gravity of the water. The column of water having descended as at K, and the wave having gone forward to W_9, the generating column remained stationary at K, thus indicating that the column of water had merely acted as a mechanical prime mover, to put in action the wave-propagating forces among the fluid, in the same way as had been formerly done by the power acting by the solid plate in the former case of genesis by impulsion. Thus is obtained a first indication that this wave exhibits *a transmission of force, not of fluid*, along the channel.

Genesis by Protrusion of a Solid.—The quantity of moving force required for the wave-genesis may be directly obtained by the descent of a solid weight. The solid at L (fig. 3.) may be a box of wood or iron, containing such weights as are desired, and suspended in such a manner as to be readily detached from its support. Its under surface should be somewhat immerged. On touching the detaching spring, the weight descends, and the water it displaces produces a wave of equal volume. If the weight and volume of solid thus immersed be equal to those of the water in the reservoir in the former case, it is found that the waves generated by the two methods are alike. It is expedient that the breadth and shape of this solid generator should be such as to fit the channel, as this removes some sources of disturbance. The results which are produced by this application of moving power are also convenient for giving measures of the mechanical forces employed in wave-genesis.

This method is especially convenient for the genesis of waves of considerable magnitude. With this view I erected a pyramidal structure of wood, capable of raising weights of several hundred pounds, over a pulley by means of a crane, and contrived to allow them to descend at will. This apparatus was adequate for the generation of waves in a channel three feet wide and three feet deep; and the same construction may be extended to greater dimensions.

Transmission of Mechanical Power by the Wave.—By the last two methods of genesis there is to be obtained a just notion of the nature of the wave of the first order as a vehicle for the transfer of mechanical power. By the agency of this wave the mechanical power which is employed in wave-genesis at one end of the channel, passes along the channel in the wave itself, and is given out at the other end with only such loss as results from the friction of the fluid. At one end, as of the channel G, fig. 4, there is placed the water, which, falling through a given height, is to generate the wave. At the other end, X, is a similar reservoir and sluice, open to the channel. When the wave has been generated as at K, and has traversed the length of the channel, it enters the receptacle X, and assuming the form marked at L, the sluice being suddenly permitted to descend, the column of water will be inclosed in the receptacle, and its whole volume raised above the level of repose nearly as at the first. The power expended in wave-genesis, having been transferred along the whole channel, is thus once more stored up in the reservoir at the other extremity. A part of this power is, however, expended *in transitu* by friction of the particles and imperfect fluidity, &c. When the channel is large, the sides and bottom smooth, the transmission of force may be accomplished with high velocity, at the rate of many miles an hour, to a distance of several miles.

Re-genesis of Wave.—In the channel AX, we have found the wave transmitted from A to X, and there the power of genesis transferred to the fluid column now stored up in the reservoir X. If we now repeat from the receptacle X the same process of genesis originally performed at G, elevating the sluice and allowing the fluid column to descend, it will again generate a wave similar to the first, only transmitted back in the opposite direction. This re-generated and re-transmitted wave may be again found in the primary reservoir of genesis as at G, and the same power, after having been transmitted twice through the length of the channel, be restored as at first in that channel, with only the small diminution of power lost *in transitu.* The process of re-genesis may now be repeated, as at first, and so on during any number of successive transmissions and re-transmissions.

Reflexion of the Wave.—This process of restoring the force employed in wave-genesis, and of re-genesis of the wave, may take place without the intervention of the sluices. The wave, on reaching the end of the channel G at X_7, becomes accumulated in the form of the curve $w\,x$. We have therefore the power of genesis now stored up in this water column, $w\,L\,x$, above the level L, and in a state of rest. By means of a sluice we may detain it at that height for as long time as we please. But let us suppose we do not wish to detain it, but allow the water column to descend by gravity as at first, it generates the wave by again descending, and transmits it back towards G, as effectually as if the reservoir had been used, or as the genesis when first accomplished. By the same process of *laissez faire*, the power of genesis will be restored at G, a water column elevated, the fluid brought to rest and allowed again to descend, again to effect genesis of the wave, and again transmit the force along the channel through the particles of the wave. The wave is said to be reflected, and it is thus shown in reference to the wave of the first order, that the process called reflexion consists in a process of restoration of the power of genesis, and of re-genesis of the wave in an opposite direction. In this manner there is to be obtained an accurate view of the mechanical nature of the reflexion of the wave.

Measure of the Power of Wave-Genesis.—If we examine the process of wave-genesis as at K, fig. 2, we find that the change which has taken place after the wave-genesis and before, consists virtually in a different arrangement of the particles of a given volume of water. The given rectangular column of water $A\,P_{10}$ occupies after genesis the equal space A K. This, without regard to the paths in which the particles have proceeded to their new places, this descent is the final result and integral effect of the development of the power of the generating column. Take away from these two equal volumes of fluid the volume $g\,p$ common to both, and the remaining volumes $w\,P$ and *p h* are equal, and a given volume of water has effectively descended from P G *w* into K *k p*, and g_1 and g_2 being the centres of gravity; the quantity of power developed is measured by the descent of the weight of water through a height $g_1 g_2$, or through half the depth of the generating reservoir, and is of course capable of generating in any equal mass of fluid a velocity equal to that which is acquired by falling through a space equal to one-half the depth, reckoned from the top of the generating column to the bottom of the channel.

Imperfect Genesis of the Wave.—The wave may be said to have imperfect genesis, as far as the purposes of accurate experiment are concerned, when it is accompanied by other wave phænomena which interfere with it. The precautions necessary to perfect genesis appear to be these, that the volume of water should not widely differ from the volume of the wave it is proposed to generate, and that the height of the water should not greatly differ from that of the wave; and even these precautions are scarcely sufficient for the generation of a perfect solitary wave in a case where it is extremely high. The reason is obvious.

Residuary Positive Wave.—In a case of genesis where the precautions mentioned above are not observed, the following phænomenon is exhibited. If, as in the case fig. 6, the volume of the generating fluid considerably exceed (in consequence of the length of the generating reservoir) the length of the wave of a height equal to that of the fluid, the wave will assume its usual form W notwithstanding, and will pass forward with its usual volume and height; it will free itself from the redundant matter *w* by which it is accompanied, leaving it behind, and this residuary wave, w_2, will follow after it, only with a less velocity, so that although the two waves were at first united in the compound wave, they afterwards separate, as at W_2 *w*, and are more and more apart the further they travel.

Disintegration of large Wave Masses.—Thus also by increasing the length of the generating column, there may be generated any number of residuary waves, and it is a result of no little importance, to just conceptions of the nature of the wave of the first order, that it be not regarded as an arbitrary phænomenon deriving all its characters from the conditions in which it was at first generated, but that it is a phænomenon *sui generis*, assuming to itself that form and those dimensions under which alone it continues to exist as a wave. The existence of a moving heap of water of any arbitrary shape or magnitude is not sufficient to entitle it to the designation of a wave of the first order. If such a heap be by any means forced into existence, it will rapidly fall to pieces and become disintegrated and resolved into a series of different waves, which do not move forward in company with each other, but move on separately, each with a velocity of its own, and each of course continuing to depart from the other. Thus a large compound heap or wave becomes resolved into the principal and residuary waves by a species of spontaneous analysis.

Residuary Negative Waves.—There is a method of genesis the reverse of the last, which also produces residuary waves, but they are thus far the reverse of the last in form, as they have the appearance of *cavities* propagated along the surface of the still water in the channel, and they move *more slowly* than the positive wave: we may give them the appellation of residuary negative waves. When the elevation of the fluid in the reservoir is great in proportion to its breadth (reckoned as amplitude), the descending column of genesis communicates motion to a greater number of particles of water than its own, but with a less velocity; these go to form a wave which is larger in volume than the column of genesis, and therefore contribute to the volume of the wave some of the water which originally served to maintain the level of the fluid or surface of repose; this hollow is transferred like a hollow wave along the fluid, and there may exist several such waves, which I have called residuary negative waves. But these waves do not accompany the primary wave, nor have they the same velocity. See O, fig. 16.

It is of some importance to note, that these residuary phænomena of wave-genesis are *not companion phænomena* to the primary wave or positive wave of the first order. They will be separately considered at another time; meanwhile it is to be noted that these residuary phænomena accompany only the genesis of the wave, but do not attend the transmission, as they are rapidly left behind by the great primary solitary wave of the first order. Certain philosophers have fallen into error in their conceptions of these experiments by not sufficiently noting this distinction.

It is worth notice also, that besides these, many other modes of genesis have been employed; solids elevated from the bottom of the channel, vessels drawn along the channel, &c.; wherever a considerable addition is made to the height and volume of the liquid at any given point in the channel, a wave of the first order is generated, differing in no way from the former, except in such particulars as are hereinafter noticed.

Motion of Transmission.—The crest of the wave is observed to move along a channel which does not vary in dimension, with a *velocity sensibly uniform*, so that the velocity with which it is transmitted may be determined by simply measuring a given distance along the channel, and observing the number of seconds which may elapse during the transit from one end of the line to the other. This interval of time is sensibly equal for any equal space measured along the path, and hence we determine that the velocity of the wave transmission is sensibly uniform.

Range of Wave Transmission.—The distance through which a wave of the first order will continue to propagate itself, is so great as to afford considerable facility for accurate observation of its velocity. For accurate observations it is convenient to allow the early part of the range to escape without observation; for this purpose, that the primary wave, which is to be the subject of observation, may disembarrass itself of such secondary phænomena as frequently accompany its genesis, when that genesis cannot be accurately accomplished. A small part of the range is sufficient for this purpose, and the remainder is perfectly adapted for purposes of accurate observation, as it continues to travel along its path long after the secondary waves have ceased to exist. The *longevity of the wave of the first order*, and the facility of observing it, may be judged of from the following experiments, made in 1835–1837.

Ex. 1. A wave of the first order, only 6 inches high at the crest, had traversed a distance of 500 feet, when it was first made the subject of observation. After being transmitted along a further distance of 700 feet, another observation was noted, and it was observed still to have a height of 5 inches, and to have travelled with a velocity of 7·55 miles an hour.

Ex. 2. A wave of the first order, originally 6 inches high, was transmitted through a distance of 3200 feet, with a mean velocity of 7·4 miles an hour, and at the end of this path still maintained a height of 2 inches.

Ex. 3. A wave 18 inches high, moving at the rate of 15 miles an hour, in a channel 15 feet deep, had still a height of 6 inches, having traversed the same space in 12 minutes.

Ex. 4. Among small experimental waves of the first order, in small channels, I have selected one, which, whose crest being 1·34 inch high, in a channel 5·10 inches deep, was transmitted through a range of 1360 feet, and still admitted of accurate observation.

These examples serve to convey an accurate idea of the longevity of a wave of the first order. And this longevity appears to increase with the depth and the breadth of the channel, and with the height of the wave crest.

Degradation of the Wave of the First Order.—In the progress of a wave of the first order, it is observed that its height diminishes with the length of its path; the velocity also diminishes with the diminution of height, though very slowly. This degradation of height is observed to go on more rapidly in proportion as the channel is narrow, shallow or irregular, and rough on the sides, and is diminished according as the channel is made smooth and regular in its form, or deep and wide. It is to be attributed to the imperfect fluidity of the water in some degree, but also to the adhesion of water to the sides. The particles of fluid near the sides and bottom are retarded in their motions, and the transmission takes place more slowly among them. The wave passes on, leaving in these particles a small quantity of the motion it had communicated, and of its force and volume, and in consequence of this there exists along the whole channel, over which the wave has passed, a residual motion or continuous residual wave, very small in amount, but still appreciable by accurate means of observation. The volume of the wave is thus diffused over a large extent along its path, where finally it has deposited the whole of its volume, and so disappears. This degradation is therefore the means by which the motion of a wave in an indefinite channel is gradually and slowly terminated. In the history of a solitary wave of the first order, the progress of this degradation is to be observed from the examination of Table II. column B, which gives the height of the wave as observed at every 40 feet along its path. In the first 200 feet this diminution amounts to about $\frac{1}{4}$ of the height at the commencement. At the end of the second 200 feet, the height is diminished by $\frac{4}{9}$ of the height at the commencement of that space. During the third space of 200 feet the degradation produced is nearly $\frac{1}{2}$ of the height of the wave; this appears to be the most rapid degradation, and in the next space of 200 feet it is little more than $\frac{1}{3}$; in the next, less than a third of the height at the beginning of that space. These successive heights are given graphically in Plate XLVIII. fig. 7.

The Velocity of Transmission of the Wave of the First Order.—The history of a single wave has sufficed to show us that the velocity with which its crest is transmitted along the channel is nearly that which a heavy body will acquire falling freely through a height equal to half the depth of the fluid. This is a very simple and important character in the phænomena of this wave, by which, when the depth of the channel is known, we may at once predict approximately the velocity of the wave of translation. The following are approximate numbers deduced from this conclusion, and which I find it convenient to recollect.

In a channel whose depth is $2\frac{1}{2}$ inches, the velocity of the wave is $2\frac{1}{2}$ feet per second.

In a channel whose depth is 15 feet, the velocity of the wave is 15 miles an hour.

In a channel whose depth is 90 fathoms, the velocity of the wave is 90 miles an hour.

These numbers are, however, only first approximations, for it is to be observed in reference to wave, Table II., that the wave, when its height is considerable, moves with greater velocity than when it is small. These numbers become accurate, if in the depth, the height of the wave be included.

The Height of the Wave of the First Order, an element in its velocity.—The height of the wave appears to enter as an element in its velocity, and to cause it to deviate from the simple formula A. Thus the velocity of the wave only coincides with the velocity assigned in Table II. when the height of the wave is inconsiderable.

I have found that this deviation is to be reconciled, without at all destroying the simplicity of the formula, by a very simple means. In order to obtain perfect accuracy, we have only to reckon the effective depth for calculation, from the ridge or crest of the wave instead of from the level of the water at rest; and having thus added to the depth of the water in repose, the height of the wave crest above the plane of repose, if we take the velocity which a heavy body would acquire in falling through a space equal to half the depth of the fluid (reckoning from the ridge of the wave to the bottom of the channel), that number accurately represents the velocity of transmission of the wave of the first order.

We have, therefore, for the velocity of the wave of the first order,

approximately $v=\sqrt{gh}$, ... A.

accurately $v=\sqrt{g(h+k)}$, ... B.

where v is the velocity of transmission,

g is the force of gravity as measured by the velocity which it will communicate in a second to a body falling freely $=32$,

h is the depth of the fluid in repose,

k is the height of the crest of the wave above the plane of repose.

The velocities of waves of the first order in channels of different depths are, therefore, as the square roots of the depth of these channels.

Nevertheless, when the height of one of the waves is considerable compared with the depth of the channel, a high wave in the shallower channel may move faster than a lower wave in a deeper channel; provided only the excess in height of the higher wave be greater than the difference of depth of the channels; in short, that wave will move fastest in a given channel whose crest is highest above the bottom of the channel, and in channels of different depths waves may be propagated with equal velocities, provided only the sum of the height of wave and standing depth of channel amount to the same quantity.

TABLE II.

History of a Solitary Wave of the First Order, from observation.

Depth of fluid in repose in the channel 5·1 inches.

Breadth of the channel 12 inches; the form rectangular.

Volume of generating column 445 cubic inches.

Column A is the observed height of the crest of the wave in inches above the bottom of the channel.

Column B is the observed height of the crest of the wave in inches above the surface of the water in repose.

Column C is the time in seconds occupied in traversing the distances in column D.

Column D is the spaces traversed by the wave in feet previous to each observation of time.

Column E is the velocity of the wave through each length of 40 feet deduced from observation.

Column F is the velocity deduced from the formula $\sqrt{g(h+k)}=v$.

A.	B.	C.	D.	E.	F.	G.
6·44	1·34	0·0	0	0·0		
6·41	1·31	9·5	40	4·21	4·15	− ·06
6·35	1·25	19·0	80	4·21	4·13	− ·08
6·26	1·16	29·0	120	4·0	4·11	+ ·11
6·16	1·06	39·0	160	4·0	4·08	+ ·08
6·05	0·95	49·0	200	4·0	4·04	+ ·04
5·86	0·76	59·0	240	4·0	3·99	− ·01
5·83	0·73	69·0	280	4·0	3·96	− ·04
5·76	0·66	79·5	320	3·81	3·94	+ ·13
5·68	0·58	89·5	360	4·0	3·91	− ·09
5·63	0·53	100·0	400	3·81	3·89	+ ·08
5·52	0·42	110·5	440	3·81	3·86	+ ·05
5·51	0·41	121·0	480	3·81	3·84	+ ·03
5·47	0·37	131·5	520	3·81	3·83	+ ·02
5·42	0·32	142·0	560	3·81	3·82	+ ·01
5·37	0·27	152·5	600	3·81	3·80	− ·01
5·36	0·26	163·0	640	3·81	3·79	− ·02
5·32	0·22	173·5	680	3·81	3·78	− ·03
5·31	0·21	184·0	720	3·81	3·77	− ·04
5·29	0·19	195·0	760	3·63	3·77	+ ·14
5·27	0·17	205·5	800	3·81	3·76	− ·05
5·26	0·16	216·5	840	3·63	3·75	+ ·12
5·25	0·15	227·5	880	3·63	3·75	+ ·12
5·24	0·14	237·5	920	4·0	3·75	− ·25
5·23	0·13	248·5	960	3·63	3·74	+ ·11
5·22	0·12	259·5	1000	3·63	3·74	+ ·11
5·20	0·10	270·0	1040	3·81	3·73	− ·08
5·19	0·09	281·0	1080	3·63	3·73	+ ·10
5·19	0·09	291·5	1120	3·81	3·73	− ·08
5·18	0·08	302·5	1160	3·61	3·72	+ ·11
						+1·36
						−0·84
						+0·52
					Mean...	+0·018

History of a solitary Wave of the First Order.—In the accompanying table is given a history of the progress of a wave from its genesis through a range of 1160 feet, and during a period of 302 seconds. This wave was generated in the manner already described, by the addition of a volume of 445 cubic inches to the fluid at one extremity of the channel. The fluid in repose had a depth of 5·1 inches, and the wave generated had a height of 1·34 inch above the plane of repose, thus making the whole depth reckoned from the crest of the wave to the bottom of the channel =5·1+1·34=6·44 inches as the depth total. This, as successively observed, forms column A, and the simple height of the wave above the plane of repose forms column B. The height of the wave is recorded at successive distances of 40 feet, as recorded in column D, reckoning from the first observation, and the corresponding time of transit past the station of observation is given in column C. The column E gives the velocity between two successive stations as resulting from the observations C and D. In order to compare these observations with the formula $v=\sqrt{g(h+k)}$, g is taken at the value 32·1908 feet, being the velocity required in one second by a body falling freely *in vacuo* in the latitude of Greenwich at the level of the sea, and $(h+k)$ is the number of inches in column A, reduced to decimals of a foot. The number resulting from these as the velocity per second which a heavy body will acquire in falling freely by gravity through a space equal to half the depth (reckoned from the crest of the wave), is that given in column F; with which the numbers in column E resulting from observation are compared, their excess or defect being set down with the signs + or — in column G.

We are thus enabled to compare the numbers given by observation E with the numbers given by formula F, and the result G shows that the coincidence is as close as the means of observation would admit. It was not possible with the chronometer then applied (although observations to fifths of a second have since been obtained) to depend upon accuracy to more minute intervals than half-seconds, and the differences in column G are precisely what we should have expected, being nearly alternately + and —, and being of nearly the same magnitude at both ends, and along the whole line of observation. The sum of the errors affected by the positive sign is +1·36, the sum of those affected with the negative sign —0·84, so that the whole of 29 observations give only an excess of +·52, or a mean excess of 0·018, showing a mean excess of velocity of the observation over the velocity assigned by the formula, of 0·018 of a foot per second, being less than $\frac{1}{200}$th of the whole. Hence we are warranted in assuming, that as far as the history of this wave is concerned, the velocity is accurately represented to within $\frac{1}{200}$th part by the formula $\sqrt{g(h+k)}=v$.

Experiments on the Velocity.—In order to determine the velocity of the wave of the first order with accuracy, a series of experiments have been made upon rectangular channels, extending from 1 inch in depth and a foot wide, to 12 feet wide and 6 feet deep. These experiments, forming a series of thirty different depths, are given in Table III. Column A contains the depth of the water, reckoned from the crest of the wave. Column B is the height of the crest of the wave above the level of the water in repose. Column C is the velocity of the wave as observed, and in column D is given the velocity due to half the depth in column A calculated by the formula $v=\sqrt{g(h+k)}$. Columns D and C are compared, and their difference given in E, from which it results that the formula represents the experiments to within a mean error of 0·007. The results of this table leave no room to doubt that, as far as observation can settle this point, the velocity is conclusively settled, and determined to be *that due by gravity through half the depth of the fluid, reckoned from the ridge of the wave.*

TABLE III.

Determination of the Velocity of the Wave of the First Order, from observation. (See Seventh Report of the British Association, and Researches on Hydrodynamics in the Philosophical Transactions of the Royal Society of Edinburgh, 1836.)

The form of the channels was rectangular.

The breadth of the channels varied from 12 inches to 12 feet.

Column A gives the depth of the channel in inches reckoned from the top of the wave.

Column B gives the height of the wave above the surface of the fluid in repose.

Column C is the velocity of the wave in feet per second, from observation.

Column D is the velocity of the wave calculated by formula B.

Column E is the difference between columns D and C.

A.	B.	C.	D.	E.	A.	B.	C.	D.	E.
1·0			1·63		6·9	0·7	4·29	4·30	+·01
1·05	0·05	1·64	1·67	+·03	7·0			4·33	
1·30	0·15	1·84	1·86	+·02	7·33	0·29	4·39	4·43	+·04
1·62	0·32	2·06	2·08	+·02	7·44	0·40	4·44	4·46	+·02
2·0			2·31		7·82	0·78	4·53	4·57	+·04
2·19	0·29	2·30	2·42	+·12	8·0	0·78	4·53	4·63	+·10
3·0			2·83		9·0			4·91	
3·10	0·16	2·87	2·88	+·01	10·0			5·18	
3·23	0·15	2·99	2·94	−·05	11·0			5·43	
3·84	0·92	3·24	3·21	−·03	15·0			6·34	
3·9	0·96	3·33	3·23	−·10	19·0			7·14	
3·97	0·81	3·26	3·26	·00	20·0			7·32	
4·0	0·19	3·33	3·27	−·06	21·0			7·50	
4·08	0·13	3·24	3·30	+·06	26·0			8·35	
4·20	0·13	3·33	3·35	+·02	27·0			8·51	
4·31	0·24	3·40	3·40	·00	28·0			8·66	
4·49	0·42	3·46	3·47	+·01	29·0			8·82	
4·61	0·74	3·52	3·51	−·01	30·0			8·97	
4·75	0·8	3·52	3·56	+·04	35·0			9·68	
5·0			3·66		42·0	3·0	10·59	10·61	+·02
5·20	0·10	3·73	3·73	·00	45·0			10·98	
5·25	0·15	3·72	3·75	+·03	50·0			11·58	
5·61	0·57	4·05	3·88	−·17	55·0			12·14	
5·82	0·72	3·90	3·95	+·05	60·0			12·68	
6·0			4·01		65·0			13·20	
6·47	0·27	4·14	4·16	+·02	70·0			13·70	
6·74	0·54	4·32	4·25	−·07	75·0	9·0	14·23	14·18	−·05
									+·66
									−·54
									+·12
								Mean..	+·004

It appeared to me at one time matter of doubt, whether waves very low in height were not somewhat slower than the velocity of the formula, and those of a large size somewhat more rapid. To determine this point, Tables IV. and V. were prepared, the former consisting of larger waves, the latter of smaller. It can scarcely be said that these tables, which are arranged exactly as the previous one, establish any distinction in this respect.

To render the results of all these experiments still more appreciable, they are graphically laid down in Plate XLVIII., the stars representing the individual experiments, and the line the formula. The coincidence is satisfactory.

TABLE IV.

Velocity of larger Waves.

A.	B.	C.	D.	E.
1·62	0·32	2·06	2·08	+·02
3·84	0·92	3·24	3·21	−·03
3·9	0·96	3·33	3·23	−·10
3·97	0·81	3·26	3·26	·00
4·49	0·42	3·46	3·47	+·01
4·52	0·56	3·47	3·48	+·01
4·61	0·74	3·52	3·51	−·01
4·75	0·8	3·52	3·56	+·04
5·61	0·57	4·05	3·88	−·17
5·80	0·7	4·0	3·94	−·06
5·82	0·72	3·90	3·95	+·05
6·75	0·5	4·13	4·25	+·12
6·86	0·61	4·21	4·28	+·07
6·9	0·7	4·29	4·30	+·01
7·82	0·78	4·53	4·57	+·04
7·84	0·8	4·43	4·58	+·15
7·87	0·83	4·53	4·59	+·06
8·0	0·78	4·53	4·63	+·10
				+·68 −·37
				+·31
			Mean..	+·017

TABLE V.

Velocity of smaller Waves.

A.	B.	C.	D.	E.
1·0			1·63	
1·05	0·5	1·64	1·67	+·03
1·30	0·15	1·84	1·86	+·02
2·0			2·31	
2·19	0·29	2·30	2·42	+·12
3·0			2·83	
3·10	0·16	2·87	2·88	+·01
3·23	0·15	2·99	2·94	−·05
4·00	0·19	3·33	3·27	−·06
4·08	0·13	3·24	3·30	+·06
4·20	0·13	3·33	3·35	+·02
4·31	0·24	3·40	3·40	·00
5·0			3·66	
5·20	0·10	3·73	3·73	·00
5·25	0·15	3·72	3·75	+·03
6·0			4·01	
6·40	0·15	4·04	4·14	+·10
6·47	0·27	4·14	4·16	+·02
6·74	0·54	4·32	4·25	−·07
7·0			4·33	
7·33	0·29	4·39	4·43	+·04
7·44	0·40	4·44	4·46	+·02
8·0			4·63	
				+·47 −·18
				+·29
			Mean..	+·018

Wave of the First Order not formerly described.—Although many distinguished philosophers from the time of Sir Isaac Newton have devoted themselves to the study of the theory of waves, I have not been able to discover in their works anything like the prediction of a phænomenon such as the wave of translation or the solitary wave of the first order. The waves of the second order, or gregarious oscillations, which make their appearance in successive groups, or long and recurring series, such oscillations of the surface of the water as we notice on the sea, or are excited when the quiescent surface of a lake is disturbed by dropping a stone, and which diffuse themselves in concentric circles around the centre of derangement; these have long been familiar to naturalists, and have been studied, though with comparatively little success, by philosophers. But I have not found the phænomenon, which I have called the wave of the first order, or the great solitary wave of translation, described in any observations, nor predicted in any theory of hydrodynamics.

Unquestionably the means of making such a prediction must have existed in any sound theory. It is, I think, pretty generally admitted that Lagrange was quite successful in stating the general equations of fluid motion; so that it was only necessary to obtain complete solutions of these equations to exhibit the formulæ of all motion consistent with the maintenance of continuity of the fluid and obedience to the laws of motion and pressure. After finding the general equations for the motion of incompressible fluids in the 'Mécanique Analytique,' part 2. sect. ix., Lagrange says, "Voilà les formules les plus générales et les plus simples pour la détermination rigoureuse du mouvement des fluides. La difficulté ne consiste plus que dans leur intégration;" and then he adds elsewhere, "malheureusement elles sont si rebelles, qu'on n'a pu jusqu'à présent en venir à bout que dans des cas très-limités." Indeed, ever since the publication of Euler's general formula for the motion of fluids in the Memoirs of the Academy of Sciences of Berlin, 1755, the whole phænomena of fluids in all conditions may be considered as having been represented. But the phænomena have remained there till now, locked up without any one to open, and amongst the rest I presume the wave of the first order.

There is one point, however, in which the analysis of M. Lagrange has appeared to make an approach to the representation of one of the phænomena peculiar to the wave of translation. In section xii. of part 2. of the 'Mécanique Analytique,' he investigates the propagation of vibrations in elastic fluids (like those of sound through the atmosphere), and obtains an equation

$$\frac{d^2\phi}{dt^2}=gh\left(\frac{d^2\phi}{dy^2}+\frac{d^2\phi}{dx^2}\right),$$

from which he afterwards deduces the well-known law that sound is propagated with a velocity (nearly) equal to that which is due to gravity, acting freely through a height equal to half the depth of the atmosphere (supposed homogeneous and of uniform density). And again, elsewhere he finds for the propagation of wave motion in a liquid in a channel with a level bottom, and a depth α, the equation

$$\frac{d^2\phi}{dt^2}=g\alpha\left(\frac{d^2\phi}{dy^2}+\frac{d^2\phi}{dx^2}\right);$$

and from the similarity of this to the former equation, he argues as follows: "Ainsi comme la vîtesse de la propagation du son se trouve égale à celle qu'un corps grave acquerrait en tombant de la moitié de la hauteur de l'atmosphère supposée homogène, la vîtesse de la propagation des ondes sera la même que celle qu'un corps grave acquerrait en déscendant d'une hauteur égale à la moitié de la profondeur de l'eau dans le canal."

Had this result been of the same general nature with the original equations from which it is deduced, we should have been able to assign to the analysis of M. Lagrange the honour of having predicted in 1815 the wave of the first order, never distinctly recognised by observation till 1834. Unhappily the nature of his investigation precludes us from doing so, and he goes on himself to admit that this conclusion will only apply to such waves as are infinitely small, and agitate the water to a very small depth below the surface. "On pourra toujours employer la théorie précédente, si on suppose que dans la formation des ondes l'eau n'est ébranlée et remuée qu'à une profondeur très-petite." The wave of the first order bears as its characteristics, the observed phænomena, that the agitation does extend below the surface to the very bottom of the channel, where it is quite as great as at the surface, and that its oscillations are large. The essential conditions of Lagrange's analysis being that the oscillation is minute, and that the agitation of the fluid is confined to the surface, we are precluded from the application of his formula to the wave of the first order.

I have been led to speak thus fully of M. Lagrange's solution, because his result is the only one that offers a tolerable approximation to the representation of the velocity of the wave of the first order. I do not find in the results obtained by M. Poisson in his 'Theory of Waves,' any result that represents the phænomena of this wave, although he shows that the solution of Lagrange cannot either mathematically or physically be applied to considerable depths. Nearly all of them seem to apply only to the phænomena of the fluid in the vicinity of the initial disturbance. The supposed method of genesis is one also which precludes the existence of the wave of the first order.

The greater part of the investigations of M. Poisson and of M. Cauchy under the name of wave theory, are rather to be regarded as mathematical exercises than as physical investigations; but an account of what has been accomplished in this way by them, and by M. Laplace, may be found in the excellent Reports of Mr. Challis in the Transactions of the British Association, and in the treatise of MM. Weber*.

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* I think it right in this place to mention, with such distinction as I am able to bestow, a very valuable treatise on waves, which was published nearly twenty years ago in Leipsic, by the brothers Ernest H. Weber and William Weber, entitled 'Wellenlehre auf Experimente gegründet, oder über die Wellen tropfbarer Flüssigkeiten mit Anwendung auf die Schall- und Licht-Wellen, von den Brüdern Ernst Heinrich Weber, Professor in Leipzig und Wilhelm Weber in Halle. Mit 18 Kupfertafeln. Leipzig, bei Gerhard Fleischer, 1825.' The work is distinguished by more than the usual characteristics of German industry in the collection of materials, and contains nearly all that has ever been written on waves since the time of Newton, and as a book of reference alone is a valuable history of wave research. To this synopsis of the labours of others is appended a valuable series of experiments by the Messrs. Webers themselves, contrived with much ingenuity, and conducted with apparently a high degree of accuracy, designed to illustrate, extend, contradict or confirm the various theories that have been advanced. I have been disposed to regret that this excellent book did not reach me till long after my own researches had advanced far towards completion. But if it had done so, it might have diverted me from my own trains of research. As the subject now stands, it so happens that their labours and mine do not in the least degree supersede or interfere with each other. Our respective works may be rather reckoned as supplementary the one to the other, inasmuch as a great part of what they have done I have not attempted, and the most part of what I have done will not be found in any part of their work. Of the existence of my great solitary wave of the first order they were not aware, and although I am now able to recognise its influence on their results, yet owing to the nature of their experiments, it was not likely they should recognise its existence, much less could they examine its phænomena.

The following passages serve to show that the Messrs. Weber had never recognised the existence of my solitary wave of the first order. They say in Abschnitt IV. Art. 87,—

"Waves make their appearance as heights and hollows upon the surface of the liquid, one part being raised above the level surface, and another part sunk below it; hence the height may be called the wave-ridge, and the depression the wave-hollow. These wave-ridges and wave-hollows never come singly, but always connected with one another. This is the reason why we do not call the wave-ridge by itself alone *a wave*, nor the wave-hollow by itself alone a wave, but simply the two conjoined." Art. 89. "The sum of the breadths of one wave-ridge and of its companion wave-hollow, is called the breadth of a wave." Art. 101. "But never in nature appears a wave-ridge unconnected with a wave-hollow, nor in like manner any wave-hollow without its companion wave-ridge. Also from this reason it follows that we can never have, during wave-motion, a particle of the fluid moved forward in its path without immediately before or after having a contrary motion also; nor backwards, without also its path being reversed."

Their observations on the larger class of waves are ingeniously contrived, carefully observed, and faithfully recorded, but lose much of the value as the basis of calculation and of general laws from the following circumstances:—1st, the narrowness of the channel; that in which the greater number of observations was made, being only 6·7 lines wide; from this cause so great an influence was produced by the adhesion of the sides as seriously to interfere with the phænomena, which ought not therefore to be considered as the phænomena of perfectly free fluids; 2, the shortness of the channels; the longest having a depth of 2 feet and only 6 feet of length; in this case an observation of the wave of the first order was impossible; and when we add that the wave genesis was in general produced by the descent of a water column of great height, it was impossible that in the short period of wave transit the phænomena could attain a condition of uniformity favourable to accurate observation, one second and a fraction of a second being the whole period of an observation, and it being necessary to observe accurately to at least one-twentieth of a second, the results possess little value as measures of the phænomena. In my experiments we found that the first observations immediately after the wave genesis were the

Having ascertained that no one had succeeded in predicting the phænomenon which I have ventured to call the wave of translation, or wave of the first order, to distinguish it from the waves of oscillation of the second order, it was not to be supposed that after its existence had been discovered and its phænomena determined, endeavours would not be made to reconcile it with previously existing theory, or in other words, to show how it ought to have been predicted from the known general equations of fluid motion. In other words, it now remained to the mathematician to predict the discovery after it had happened, i. e. to give an *à priori* demonstration *à posteriori*.

Theoretical Results subsequent to the publication of the Author's Investigations.—Since the publication of my former observations on the wave of the first order, two attempts have been made to elicit from the wave theory, as developed by Poisson, &c., results capable of such physical interpretations as should represent the phænomena of that order.

The first of these investigations is that of Mr. KELLAND in the Edinburgh Philosophical Transactions. This valuable and elegant investigation deduces theoretically, from the general equations of fluid motion, on the hypothesis of parallel sections, and of oscillations of the general form of the curve of sines, the following value for the velocity of a wave,

$$c^2=\frac{g}{\alpha}\cdot\frac{e^{ah}-e^{-ah}}{c^{ah}+e^{-ah}}\div\left\{1-\varepsilon a\frac{e^{ah}-e^{-ah}}{e^{ah}+e^{-ah}}\right\}, \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad [\mathrm{C.}]$$

ε being the semi-elevation, h the depth in repose, λ the length of the wave, c the velocity of transmission.

This expression gives values for the velocity of the wave which Mr. Kelland has himself compared with my experiments as follows:—

Theoretical value when $h=3{\cdot}97$ and $2e=0{\cdot}53$, is $c=2{\cdot}8693$
Observed value $c=3{\cdot}38$,

showing the error in defect $=-\frac{1}{5\frac{1}{2}}$ or $-\frac{2}{11}$ of the whole theoretical velocity.

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least accurate and the least valuable, and these are the *only* observations employed by MM. Weber in their larger wave observations. Further, as they did not recognise at all the possibility of the existence of the solitary wave of the first order, nor the difference of its phænomena from the negative waves, nor the distinction of waves into separate first and second orders, they have mingled together the observations and phænomena of both. Thus have they failed to recognise the existence of the law of the velocity which I have elicited.

Nevertheless, their observations are very valuable, and furnish interesting information to one already master of my observations. In their very deviations from the laws exhibited by my observations, they become instructive as manifesting and enabling us to measure the amount of those interfering influences which diminished the value of their experiments when taken by themselves. For this purpose I have taken some of their experiments and placed them beside the results of mine; the effects of adhesion to the sides, and of more or less perfect fluidity, are well manifested in the difference of the results. It is however to be remembered that in point of accuracy and precision, and also of weight, the shortness of period and path in their observations diminish their value.

These remarks, which I make with perfect deference, are designed to apply only to the large class of waves to which chiefly I have directed my attention; the observations on dropping waves, and all those made with reference to the phænomena of light and sound, are to be exempted from these remarks. I desire that my experiments should enhance rather than derogate from the value of those of my estimable predecessors, and I wish rather by these statements to make an apology to them for having arrived at different conclusions, by showing that the methods I chanced to light upon, and the circumstances in which I observed, were more favourable than those which they happened to employ. I only aspire to having brought to a more favourable conclusion what they had most meritoriously begun under circumstances less propitious; my having arrived at different conclusions is probably more owing to the chance of my being ignorant of their methods when I began, and alighting by chance upon better; for had I known of their elegant apparatus at first, it is not improbable that I should have been satisfied to adopt what so much ingenuity had contrived, and so failed to extend the subject beyond the conclusions they had attained.

Another example:

Theoretical value (when $h=1$ and $2e=0{\cdot}3$) $c=1{\cdot}547$
Observed value $c=1{\cdot}8$,

showing the error in defect $=-\frac{1}{6}$ of the whole theoretical velocity.

Again,

Theoretical value (when $h=7{\cdot}04$ and $2e=0{\cdot}89$) $c=4{\cdot}0$
Observed value $c=4{\cdot}6$,

showing the error in defect $=-\frac{1}{8}$ of the whole theoretical velocity.

I think it due to Mr. Kelland to say, that notwithstanding all the anxiety for success which naturally exists in the mind of one who has bestowed much time and talent on perfecting, as he has done, an elegant theory; he has not yielded to the temptation of twisting his theory to exhibit some apparent approximation to the facts, nor distorted the facts to make them appear to serve the theory, a proceeding not without precedent; but he has candidly stated the discrepancy, and says, "my solution can only be regarded as an approximation, nor does it very accurately agree with observation." This is a candour which cannot be too highly valued, and can only be justly appreciated by those who have, as I have, after working at a favourite theory, it may be for months and years, found it necessary to abandon it, and make the sacrifice for the sake of truth with readiness and candour.

Mr. Airy has followed Mr. Kelland over the same ground, in an elaborate paper on waves in the 'Encyclopedia Metropolitana,' published since the greater part of this Report was ready for the press. This paper I have long expected with much anxiety, in the hope that it would furnish a final solution of this difficult problem, or at least tend to reduce the number and extent of the unhappy discrepancies between the wave-prediction and the wave-phænomena, a hope justified by the reputation and position of the author, as well as by the clear views and elegant processes which characterize some of his former papers.

Mr. Airy has obtained for the velocity of a wave, an expression of a form closely resembling that which Mr. Kelland had previously obtained, viz.

$$c^2=\frac{g}{m}\cdot\frac{\varepsilon^{mk}-\varepsilon^{-mk}}{\varepsilon^{mk}+\varepsilon^{-mk}}. \quad \ldots\ldots\ldots \quad [\mathrm{D.}]$$

From the resemblance of this form of expression to the form previously given by Mr. Kelland, we are prepared for the conclusion that Mr. Airy has advanced in this direction little beyond his predecessor. And we accordingly find that a theory of the wave of the first order, accurately representing this characteristic phænomenon, is still wanting, a worthy object for the enterprise of a future wave-mathematician.

I have already stated that I have found, that by introducing the element of the wave's height into Lagrange's formula, I get the expression

$$v=\sqrt{g(h+k)},$$

and that I find it represent with great accuracy the characteristic velocity of the wave of the first order. As however Mr. Airy appears to intimate to his readers that his own formula is as close an approximation to my experiments as the nature of these experiments will warrant, I have thought it necessary to make a complete re-examination of my experiments, and to make a laborious comparison of the phænomena discussed after the best modern methods employed in inductive philosophy; the results of these discussions I have presented in a series of graphic representations, which will enable the reader at once to attain a sound conclusion on the question, whether the formula

Mr. Airy has adopted, or that which I have always used, more truly represents the phænomena.

In the following table, E represents the velocity of the wave of the first order as taken from my observations by Mr. Airy himself. I have placed beside these results of experiments, the number given in column F, by the formula which I use to represent them. In the next four columns are Mr. Airy's numbers, calculated by himself, according to four different formulæ, which he appears here to have applied as a sort of tentative process for the purpose of selecting the one which should prove on trial least defective. I have next given five columns, which exhibit the results of comparing the phænomena of experiment with the results of the formulæ. The first of these columns represents the defects of my formula, the others those of Mr. Airy's.

The results of the first table are as follows:—

The errors of Mr. Airy's first column amount to	2635
The errors of Mr. Airy's second column amount to........	1994
The errors of Mr. Airy's third column amount to	1674
The errors of Mr. Airy's fourth column amount to........	1680
The errors of mine amount to	406

The greatest error of Mr. Airy's first column is....	809
The greatest error of Mr. Airy's second column is..	690
The greatest error of Mr. Airy's third column is ..	463
The greatest error of Mr. Airy's fourth column is..	575
The greatest error of mine is	87

The results of the second table are as follows:—

The errors of Mr. Airy's first column amount to..........	6157
The errors of Mr. Airy's second column amount to........	3350
The errors of Mr. Airy's third column amount to	3226
The errors of Mr. Airy's fourth column amount to........	2274
The errors of mine amount to	447

The greatest error of Mr. Airy's first column is....	911
The greatest error of Mr. Airy's second column is..	689
The greatest error of Mr. Airy's third column is ..	473
The greatest error of Mr. Airy's fourth column is..	480
The greatest error of mine is	122

Table VI.

Small Waves.

Column	A	is a mean height of wave crest.	As taken from my experiments by Mr. Airy.
„	B	the selected examples from which A is taken.	
„	C	the depth of the fluid in repose.	
„	D	the height of the wave.	
„	E	the velocity of the wave observed.	
„	F	the velocity of the wave as given by my formula.	
„	G	the velocity of the wave as given by Mr. Airy's first formula.	
„	H	the velocity of the wave as given by Mr. Airy's second formula.	
„	K	the velocity of the wave as given by Mr. Airy's third formula.	
„	L	the velocity of the wave as given by Mr. Airy's fourth formula.	
„	F′	the difference between observation and my formula.	
„	G′	the difference between observation and Mr. Airy's first formula.	
„	H′	the difference between observation and Mr. Airy's second formula.	
„	K′	the difference between observation and Mr. Airy's third formula.	
„	L′	the difference between observation and Mr. Airy's fourth formula.	

A.	B.	C.	D.	E.	F.	G.	H.	K.	L.
1·075	1·05 and 1·10	1·000	0·075	1·670	1·697	1·629	1·689	1·803	1·747
1·3	1·3	1·150	0·150	1·810	1·867	1·744	1·854	2·057	1·958
3·17	3·09—3·23	2·963	·207	2·860	2·915	2·702	2·795	2·972	2·885
3·36	3·32 and 3·40	3·080	·280	2·960	3·002	2·747	2·869	3·099	2·986
4·16	4·0 —4·31	3·903	·256	3·310	3·340	3·016	3·114	3·300	3·208
5·34	5·20—5·5*	5·088	·252	3·758	3·784	3·303	3·384	3·540	3·463
6·52	6·4 —6·65	6·220	·304	4·094	4·181	3·495	3·579	3·742	3·662
7·51	7·42—7·7	7·040	·474	4·406	4·488	3·597	3·716	3·943	3·831

Differences.

F′.	G′.	H′.	K′.	L′.
+·027	− ·041	+ ·019	+ ·133	+ ·077
+·057	− ·066	+ ·044	+ ·247	+ ·148
+·055	− ·158	− ·065	+ ·112	+ ·025
+·042	− ·213	− ·091	+ ·139	+ ·026
+·030	− ·294	− ·196	− ·010	− ·102
+·026	− ·455	− ·374	− ·218	− ·295
+·087	− ·599	− ·515	− ·352	− ·432
+·082	− ·809	− ·690	− ·463	− ·575
+·406	−2·635	−1·931 + ·063	−1·043 + ·631	−1·404 + ·276
·406	−2·635	1·994	1·674	1·680

TABLE VII.

Large Waves.

Columns A, B, C, &c. correspond to those in Table VI.

A.	B.	C.	D.	E.	F.	G.	H.	K.	L.
1·20	1·20	1·000	0·200	1·760	1·794	1·629	1·785	2·061	1·928
1·62	1·62	1·300	·320	2·060	2·083	1·858	2·072	2·446	2·267
2·19	2·19	1·900	·290	2·300	2·422	2·217	2·380	2·677	2·533
3·38	3·35—3·41	2·960	·420	3·010	3·010	2·701	2·887	3·225	3·061
3·55	3·5 —3·61	3·020	·532	3·080	3·085	2·724	2·954	3·368	3·168
3·83	3·69—3·97	3·007	·830	3·252	3·204	2·719	3·072	3·677	3·388
4·53	4·4 —4·75	3·910	·625	3·505	3·485	3·018	3·250	3·671	3·467
5·21	5·21	3·870	1·340	3·820	3·738	3·007	3·488	4·293	3·911
5·76	5·61—5·82	5·070	0·692	3·970	3·930	3·300	3·518	3·917	3·723
6·24	6·15—6·40	5·080	1·160	4·170	4·090	3·302	3·659	4·286	3·985
6·69	6·69—7·20	6·034	0·823	4·262	4·234	3·468	3·697	4·117	3·912
7·83	7·74—8·0	6·946	0·884	4·497	4·582	3·586	3·808	4·216	4·017

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* Excluding 5·21.

Differences.

F′.	G′.	H′.	K′.	L′.
+·034	− ·131	+ ·025	+ ·301	+ ·168
+·023	− ·202	+ ·012	+ ·386	+ ·207
+·122	− ·083	+ ·080	+ ·377	+ ·233
+·00	− ·309	− ·123	+ ·215	+ ·051
+·005	− ·356	− ·126	+ ·288	+ ·088
−·048	− ·533	− ·180	+ ·425	+ ·136
−·020	− ·487	− ·255	+ ·166	− ·038
−·082	− ·813	− ·332	+ ·473	+ ·091
−·040	− ·670	− ·452	− ·053	− ·247
−·080	− ·368	− ·511	+ ·116	− ·185
−·028	− ·794	− ·565	− ·145	− ·350
+·085	− ·911	− ·689	− ·281	− ·480
−·298 +·269	−6·157	−3·233 + ·117	+2·747 − ·479	+ ·974 −1·300
·567	6·157	3·350	3·226	2·274

The conclusion which Mr. Airy deduces from this comparison is somewhat surprising, "we think ourselves fully entitled to conclude from these experiments that the theory (Mr. Airy's) is entirely supported"! This conclusion being so completely the opposite of that to which we should be led on the same grounds, it has appeared necessary to make a still more complete re-examination and discussion of all the experiments in our possession, to see whether from any or the whole of them there should appear to be any ground for a conclusion so contrary to the apparent phænomena.

I have, therefore, directed the whole of the experiments to be re-discussed*. They are graphically represented in the diagrams on Plates XLVIII. and XLIX., which, and the description, the reader is requested to examine carefully. The result of the whole is, that there is an irresistible body of evidence in favour of the conclusion that Mr. Airy's formulæ do not present anything like even a plausible representation of the velocity of the wave of the first order, and that the formula I have adopted does as accurately represent them as the inevitable imperfections of all observations will admit. It is deeply to be deplored that the methods of investigation employed with so much knowledge, and applied with so much tact and dexterity, should not have led him to a better result.

Table VIII.

Re-discussion of the Observations by the Method of Curves.

The observations of height and time were laid down on paper, as shown in Plate XLIX. (see description), each star representing an individual observation of height or time. The curves being drawn through among the observations, were taken to represent the *corrected observations*, and the *velocity* was then deduced from the corrected observation of *time* and *height.* The table consists of results of this process.

Column A gives the corrected depth in inches $(h+k)$ of my formula.

Column B gives the corrected time in seconds employed in describing 40 feet.

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* For the accuracy and good faith with which these discussions were all conducted, I am indebted to my valued assistant Mr. I. Currie.

Column C gives the derived velocity of the wave.

Column D gives the characteristic number of the individual wave as observed (see former Report).

These results are compared with my formula in Plate XLIX.

A.	B.	C.	D.	A.	B.	C.	D.	A.	B.	C.	D.	A.	B.	C.	D.
	s.	ft.			s.	ft.			s.	ft.			s.	ft.	
3·20	14·0	2·85	26	4·24	11·8	3·39	3	5·07	11·0	3·63	∞	6·41	9·8	4·08	50
3·20	13·9	2·87		4·30	11·7	3·41						6·42	9·8	4·08	
3·20	13·7	2·92		4·36	11·7	3·41		5·18	11·0	3·63	45	6·44	9·7	4·12	
3·21	13·6	2·94		4·43	11·7	3·41		5·18	10·9	3·66		6·46	9·7	4·12	
3·22	13·5	2·96						5·19	10·9	3·66		6·48	9·7	4·12	
3·24	13·4	2·98		4·05	12·3	3·25	1	5·20	10·9	3·66		6·51	9·7	4·12	
3·27	13·3	3·00		4·06	12·2	3·27		5·21	10·8	3·70		6·54	9·6	4·16	
3·30	13·2	3·03		4·08	12·2	3·27		5·22	10·8	3·70		6·57	9·6	4·16	
3·35	13·1	3·05		4·10	12·1	3·30		5·23	10·8	3·70		6·60	9·5	4·21	
3·40	13·0	3·07		4·12	12·0	3·33		5·25	10·7	3·73		6·63	9·5	4·21	
3·45	12·9	3·10		4·14	12·0	3·33		5·27	10·7	3·73		6·68	9·5	4·21	
3·53	12·8	3·12		4·17	11·9	3·36		5·29	10·7	3·73		6.73	9·5	4·21	
3·61	12·7	3·15		4·20	11·9	3·36		5·31	10·7	3·73		6·78	9·4	4·25	
3·72	12·6	3·17		4·23	11·9	3·36		5·33	10·6	3·77		6·83	9·4	4·25	
3·84	12·5	3·20		4·27	11·8	3·39		5·35	10·6	3·77		6·89	9·4	4·25	
3·97	12·4	3·22		4·32	11·8	3·39		5·38	10·5	3·81		6·95	9·4	4·25	
				4·36	11·7	3·41		5·41	10·5	3·81		7·02	9·4	4·25	
3·97	12·5	3·20	2	4·42	11·7	3·41		5·44	10·4	3·84		7·19	9·3	4·30	
4·00	12·3	3·25		4·48	11·6	3·44		5·48	10·4	3·84					
4·03	12·1	3·30						5·52	10·3	3·88		6·70	9·16	4·16	49
4·07	12·0	3·33		4·26	12·2	3·27	∞	5·57	10·3	3·88		6·81	9·5	4·21	
4·12	11·9	3·36		4·28	12·1	3·30		5·63	10·2	3·92		6·95	9·4	4·25	
4·17	11·9	3·36		4·30	12·0	3·33		5·70	10·2	3·92		7·10	9·3	4·30	
4·22	11·8	3·39		4·32	11·9	3·36		5·78	10·15	3·94		7·30	9·2	4·34	
4·28	11·8	3·39		4·35	11·8	3·39		5·87	10·1	3·96		7·52	9·1	4·39	
4·34	11·7	3·41		4·38	11·7	3·41		5·97	10·0	4·0		7·66	9·0	4·44	
4·42	11·7	3·41		4·42	11·6	3·44		6·10	10·0	4·0					
4·49	11·6	3·44		4·46	11·5	3·47		6·2	10·0	4·0		6·71	9·4	4·25	48
				4·51	11·5	3·47		6·29	9·95	4·02		6·79	9·3	4·30	
4·04	12·2	3·27	3	4·57	11·4	3·50		6·37	9·9	4·04		6·92	9·2	4·34	
4·06	12·1	3·30		4·63	11·3	3·54		6·43	9·8	4·08		7·20	9·1	4·39	
4·08	12·0	3·33		4·70	11·3	3·54						7·54	9·0	4·44	
4·11	11·9	3·36		4·77	11·2	3·57		6·38	9·95	4·02	50	7·75	8·9	4·49	
4·15	11·8	3·39		4·85	11·2	3·57		6·39	9·9	4·04		7·82	8·8	4·54	
4·20	11·8	3·39		4·95	11·1	3·60		6·40	9·8	4·08					

Table IX.

Velocity due to a Wave of the First Order,

Obtained from the re-discussion of the experiments as described above.

Column A gives the depth in inches reckoned from the wave crest.

Column B gives the observed time of describing 40 feet, * the observations thus marked being over half that space.

Column C gives the observed velocity.

Column D is a reference to the ordinal number of the wave observed.

The close approximation of these velocities of observation with the numbers of the formula, proves at once the accuracy of the one and the truth of the other.

A.	B.	C.	D.	A.	B.	C.	D.	A.	B.	C.	D.	A.	B.	C.	D.
	s.	ft.			s.	ft.			s.	ft.			s.	ft.	
1·5	10·1*	1·98	35	4·0	12·5	3·20	3	4·5	11·5	3·47	15	5·5	10·5	3·80	46
2·0	8·7*	2·30	36	4·0	11·8	3·39	25	4·5	12·0	3·33	17	6·0	9·9	4·04	43
2·5	7·2*	2·77	36	4·0	6·0*	3·33	37	4·5	11·7	3·42	19	6·0	10·0	4·0	45
2·5	8·4*	2·38	35	4·0	6·1*	3·27	38	4·5	12·3	3·25	23	6·0	10·0	4·0	46
3·0	7·5*	2·66	40	4·0	6·0*	3·33	39	5·0	11·1	3·60	8	6·5	9·5	4·21	46
3·0	7·4*	2·70	41	4·0	6·2*	3·22	40	5·0	11·4	3·50	9 and 10	6·5	9·8	4·08	49
3·5	13·7	2·92	25	4·5	11·5	3·47	1	5·0	10·9	3·67	15	6·5	9·7	4·12	50
3·5	12·8	3·12	26	4·5	11·6	3·45	2	5·0	10·7	3·73	17	7·0	9·3	4·3	46
3·5	6·4*	3·12	37	4·5	12·0	3·33	4	5·0	10·9	3·67	19	7·5	9·2	4·35	53
3·5	6·2*	3·22	38	4·5	11·8	3·39	5	5·0	11·2	3·57	22	7·5	9·0	4·44	55
3·5	6·5*	3·07	40	4·5	11·4	3·50	6	5·0	11·1	3·60	23	8·0	8·9	4·49	51
3·5	6·5*	3·07	41	4·5	11·5	3·47	7	5·5	11·0	3·63	9 and 10	8·0	8·7	4·6	52
3·5	12·8	3·12	42	4·5	11·5	3·47	8	5·5	10·6	3·77	43	8·0	8·6	4·65	54
4·0	12·3	3·25	2	4·5	11·5	3·47	13	5·5	10·3	3·88	45	8·0	8·9	4·49	55

The Magnitude and Form of the Wave of the First Order.—This is one of the subjects to which, since the date of the former Report, I have devoted a good deal of attention. The exact determination of the dimensions and form of the wave, although at first sight it may seem simple enough, is not without peculiar difficulties. When it is observed that the two extremities of the wave are vertices of curves of very small curvature tangent to the plane of repose, it will be understood how difficult it is to detect the place of contact with precision. A variety of methods have been tried: reflexion of an image from the surface, tangent points applied to the surface so as to be observed simultaneously at both ends of the wave, and the self-registration of a float moved by the wave have all been tried with various success. On the whole, however, the most perfect observations have been obtained by a very simple autographic method, in which it was contrived that the wave should leave its own outline delineated on the surface without the intervention of any mechanism*. The method was simply this: a dry smooth surface was placed over the surface of the water in the channel, with such arrangements that it could be moved along with the velocity of transmission of the wave, and at the instant of observation it was pushed vertically down on the wave, and raised out again without sensibly disturbing the water; the surface when brought out, brought with it a moist outline of the wave, which was immediately traced by pencil, and afterwards transferred to paper. I have given a few of these autographic types of the wave in Plates L. and LI., the engravings being precise copies of the lines as drawn by the wave itself.

Another method of obtaining an autographic representation of waves of the first order was this. Two waves were generated at opposite ends of the same channel at given instants of time, so that by calculating their velocities they should both reach a given spot at the same instant; here a prepared surface was placed, and as one passed over the other it left a beautiful outline of the excess in height of each point of one wave above the summit height of the other. These forms are not identical with those of the same wave moving along a plane surface, but as true registers of actual phænomena they are interesting.

The results of all my observations on this subject are as follows:—

That the wave of the first order has a definite *form and magnitude* as much characteristic of it as the uniform velocity with which it moves, and

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* I find that I am not the first person who employed an apparatus of this sort. MM. Webers employed a powdered surface to register the form of agitated mercury, the fluid rubbing off the powder.

depending like that velocity only on the depth of the fluid and the height of the wave crest.

That this wave-form has its surface wholly raised above the level of repose of the fluid. This is what I mean to express by calling this wave *wholly positive*. I apply the word negative to another kind of wave whose surface exhibits a depression below the surface of repose. The wave-proper of the first order is wholly positive.

The simple elementary wave of the first order assumes a definite *length equal to about six times the depth of the fluid below the plane of repose.* When the height of the wave is small the length does not sensibly differ from that of the circumference of a circle whose radius is the depth of the fluid; or h being the depth of the fluid in repose, the length of the wave is represented by the quantity $2\pi h$, π being the number 3·14159, we may use this notation,

$$\lambda = 2\pi h \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{E.}$$

The length, therefore, increases with the depth of the fluid directly, being equal to about 6·28 times the depth. The length does not, like the velocity of the wave, increase with the height of the wave in a given depth of fluid. On the contrary, the length appears to diminish as the height of the wave is increased, and the length of the wave when thus corrected is

$$\lambda = 2\pi h - \alpha \quad . \quad . \quad . \quad . \quad \text{F.}$$

the value of α will be afterwards examined.

The form of the wave surface when not large is a surface of single curvature, the curvature being in the longitudinal and vertical planes alone, and the curve is the curve of sines, or rather of versed sines, the horizontal ordinates of which vary as the arc and the vertical ordinates, as the versines of a circle whose radius is the depth of the fluid in repose, $2\pi h$ being the length of the wave, and $\frac{2\pi}{m}$ an arc of that circle $=\theta$. We have for the equation of the wave curve,

$$x = h\theta$$
$$y = \tfrac{1}{2}k.\ \text{versin}\ \theta \quad . \quad . \quad . \quad . \quad \text{G.}$$

the height of the wave being denoted by k, reckoned above the plane of repose of the surface of the fluid.

The height of the wave above the surface of the water in repose may increase till it be equal to the depth of the fluid in repose. When it approaches this height it becomes acuminate, finally cusped, and falls over breaking and foaming with a white crest. The limits of the wave height are, therefore,

$$k = 0, \text{ and } k = h \quad . \quad . \quad . \quad \text{K.}$$

that is to say, the height of the wave may increase from 0 to k, but can never exceed a *height* above the level of repose equal to the *depth* of the fluid in repose; that is, the height total reckoned from the bottom is never greater than twice the depth of the fluid in repose.

The absolute Motions of each Water-Particle during Wave-Transmission.—This is one of the subjects on which, prior to last Report, I had not made a sufficient number of observations to enable me to make a full report. The methods I had employed for such observations as I had then already made, were the observation of the motions of small particles visible in the water of the same, or nearly the same specific gravity with water, or small globules of wax connected to very slender stems, so as to float at required depths. The motions of these were observed from above, on a minutely divided surface on the bottom of the channel, and from the side through glass windows, themselves accurately graduated, the side of the channel opposite to the window being covered with lines at distances precisely equal to those on the window and similarly situated. These methods are the only methods of observation I have found it useful to employ, but I have now increased the number and variety of the observations sufficiently to enable me to adduce the conclusions hereinafter following, as representing the phænomena as far as their nature will admit of accurate observation.

It is characteristic of waves that the *apparent motion visible on the surface* of the water is of one species, while the *absolute motion of the individual particles* of the water is very different. In reference to all the species of waves this is true, both as regards the velocity and nature of the motion; nevertheless the one is the immediate cause or consequence of the other. In the case of the wave of the first order, the visible motion of the wave form along the surface of the water may be called the *motion of transmission,* the actual motion of the particles themselves is to be distinguished as the *motion of translation.*

We infer the motions of the individual wave particles from those of visible small bodies floating in the water; any minute particle floating on the surface will sufficiently indicate the motion of the water particles about it, and the motion of deeper particles may be conveniently observed in the case of waves of the first order, by using the little globules of wax already mentioned; these small globules may be so made as to float permanently at any given depth, yet they will be visibly affected by very minute forces.

In this way the following observations were made:

Absolute Motion of Translation.—The phænomenon of translation characteristic of the wave of the first order, and which we have used as its distinguishing appellation, is to be observed as follows. Floating globules, as already described, being placed in the fluid, and their positions being noted with reference to the sides and bottom of the channel, let a wave of the first order be transmitted along the fluid; it is found that the effect of this transmission is to lift each of the floating particles, and similarly, therefore, the water particles themselves, out of their positions, and to transfer them permanently forward to new positions in the channel, and in these new positions the particles are left perfectly at rest, as in their original places in the channel.

The measure or range of translation is just equal to that which would result from increasing the column of water in the channel behind the wave by a given quantity, and diminishing the column anterior to the particles by the same quantity, that quantity being equal to the volume of the wave. That is to say, *the range of translation is simply equal to the space in length of the channel which the volume of the wave would occupy* on the level of the water in repose.

The *total effect* of having transmitted a wave of the first order along a channel, is to have moved successively every particle in the whole channel forward, through a space equal to the volume of the wave divided by the water-way of the channel.

Parallelism of Translation.—If the floating spherules before mentioned be arranged in repose in one vertical plane at right angles to the direction of transmission, and carefully observed during transmission, it will be noticed that the particles remain in the same plane during transmission and repose in the same place after transmission.

It is further found, as might be anticipated from the foregoing observations, that a thin solid plane transverse to the direction of transmission, and so poised as to float in that position, does not sensibly interfere with the motion of translation or of transmission.

The Range of Horizontal Translation is equal at all Depths.—Vertical excursions are performed by each particle of fluid simultaneously with the horizontal translation. These diminish in extent with the distance from the bottom when they become zero.

The Path of each Water Particle during Translation lies wholly in a Vertical Plane.—It may be observed by means of the glass windows already mentioned, its surface being graduated for purposes of measurement. The path is so rapidly described that I do not think any measurements of time which I have made, nor even of paths is *minutely* correct. The following observations are such as a practised eye with long experience and much pains has made out.

When a wave of the first order in transmission makes a transit over floating particles in a given transverse plane, the observations are as follows. All the particles begin to rise, scarcely advancing; they next advance as well as rise; they cease to rise but continue advancing; they are retarded and come to rest, descending to their original level. The path appears to be an ellipse whose major axis is horizontal and equal to the range of translation; the semi-minor axis of the elliptic path is equal to the height of the wave near the surface, and diminishes directly with the depth.

The results of these observations are, therefore, as follows:—representing by b the breadth of the channel, by h the depth of the fluid, by α the range of translation, and by v the volume of water employed in forming the waves; we have for every particle throughout the breadth and depth of the fluid

$$\alpha=\frac{v}{bh} \quad . \quad . \quad . \quad . \quad . \quad . \quad (\text{L.})$$

which everywhere measures the horizontal range of translation.

The range of vertical motion of each particle at the surface during translation being everywhere

$$y=k \quad . \quad . \quad . \quad . \quad . \quad . \quad (\text{M.})$$

we have for the vertical range y' of any other particle at a depth h' below the surface,

$$y'=\frac{h'}{h}.k \quad . \quad . \quad . \quad . \quad . \quad (\text{N.})$$

being directly as the height of the particle in repose above the bottom of the channel.

Also throughout the whole period of translation we have the height of a particle of the surface above its place of repose represented by

$$y=\tfrac{1}{2}k \operatorname{versin}\theta \quad . \quad . \quad . \quad . \quad . \quad . \quad (\text{O.})$$

and the height of any other particle in the same vertical plane at the same place represented by

$$y'=\tfrac{1}{2}\frac{h'k}{h} \operatorname{versin}\theta \quad . \quad . \quad . \quad . \quad . \quad (\text{P.})$$

The whole of these results are united in the following Table of wave phænomena.

TABLE X.

Phænomena of Wave of the First Order.

Let c be the velocity of wave transmission;
h the depth of fluid in repose;
k the height of wave-crest above surface of repose;
b breadth of channel;

v the volume of fluid constituting the wave;
g the measure of gravity;
α the horizontal range of translation;
λ the wave length or amplitude;
θ an arc $\frac{2\pi}{m}$, m being an arbitrary number;
ψ the arc whose sine $= \frac{1}{2}$ versed sine of θ;
π the number 3·1416;
π' the circumference of an ellipse whose axes are given;
x and y horizontal and vertical ordinates of wave-curve;
x' and y' horizontal and vertical ordinates of translation-path;
h' the height of a particle in repose, above the bottom of the channel.

Then we have

(1.) For velocity of wave transmission,

$$c=\sqrt{g(h+k)} \quad \ldots\ldots\ldots \quad \text{B.}$$

$$=\sqrt{gh} \text{ nearly, when } h \text{ is small} \quad \ldots\ldots \quad \text{A.}$$

(2.) For the wave length,

$$\lambda=2\pi h-\alpha \quad \ldots\ldots\ldots \quad \text{F.}$$

$$=2\pi h \text{ nearly, when } k \text{ is small} \quad \ldots\ldots \quad \text{E.}$$

(3.) For the range of translation,

$$\alpha=\frac{v}{bh} \text{ always,}$$

$$=\pi k \text{ when } k \text{ is small, } = 2\,k \text{ nearly when } k \text{ is large} \quad \text{L.}$$

(4.) For the wave form,

$$x=h\theta-x'=h\theta, \text{ when } k \text{ is small}$$

$$y=\tfrac{1}{2}k.\text{ versin }\theta \quad \ldots\ldots\ldots \quad \text{G}'$$

(5.) For the path of translation,

$$\left.\begin{array}{l} x'=\alpha \text{ versin } \psi \\ y'=\tfrac{1}{2}k \text{ versin } \theta \end{array}\right\} \quad \ldots\ldots\ldots \quad \text{O}'.$$

and below the surface at h', $y'=\frac{h'k}{2h}$. versin θ. $\ldots\ldots\ldots$ P.

(6.) The limits of the value of k are as follows:—
Inferior limit $k=0$, and $k=h$ superior limit $\ldots\ldots$ K.

(7.) The range of vertical motion of a particle during translation being $y=k$ at the surface; the range of vertical motion of any other particle at the height h above the bottom is

$$y'=\frac{h'}{h}k. \quad \ldots\ldots\ldots \quad \text{N}'.$$

Geometrical Representation of the Wave of the First Order.—These data enable to approximate to the exact conception of the motions of the wave particles, and the relations which the wave form and the particle path bear to each other. We may thus construct a geometrical representation of the wave motion, which, however, is to be carefully distinguished from a physical determination of its phænomena.

Let us then endeavour to follow the motion of a given particle on the surface of the fluid during the wave form transmission.

Let us take D E for the depth of the fluid. (Plate LII. fig. 3.)

Let us take C D for the height of the wave.

Let us mark off d D d' = the circumference of the circle of which D E is the radius = 6·2832 × D E. Let also semicircles be described on $c\,d$ and on $c'\,d'$ each equal to C D. Let the semicircles $c\,d$ and $c'\,d'$ and the distances

d D and D d' be divided into the same number of equal parts. Let there be drawn through each division of the circles horizontal lines, and through each division of the wave lengths let there be drawn perpendiculars, meeting successively the horizontal lines in 9, 8, 7, 6, 5, 4, 3, 2, 1,—these will be points in the *curve of versed sines*, that is of the (approximate) form of the wave. If, therefore, we conceive the wave-form to move horizontally and uniformly along the line d D d', and at the same time a particle of water on the surface to rise successively to the heights 1, 2, 3, 4, 5, and fall vertically to 6, 7, 8, 9, on the diameters $c\,d$ and $c'\,d'$, then the place of the particle will always coincide with the wave curve.

This is the same form (only wholly positive) which Laplace assigns to the tide wave in the 'Mécanique Céleste,' tom. iii. liv. iv. chap. iii. Art. 17. "Concevons un cercle vertical, dont la circonférence en partant du point le plus bas, expriment les temps écoulés depuis la basse; les sinus verses de ces arcs, seront les hauteurs de la mer, qui correspondent à ces temps." Or as he says elsewhere, "Ainsi, la mer en s'élevant, baigne en temps égal, des arcs égaux de cette circonférence." So if we imagine a circular disc placed vertically so as to touch the surface of the water in repose, the passing wave will in successive equal times cover equal successive arcs of the circumference.

The wave is of this form when its height is small, and the deviation increases with the increase of height.

Vertical Motion of each Particle.—No more then is necessary to the exhibition of the wave curve than that every particle of the surface of the water should be made to rise and fall successively, according to the increase and decrease of the versed sines of the circle of height. Let us follow the motion of a single particle. Draw $c'\,d'$ a vertical diameter of the wave circle, suppose C $e\,f\,g\,h\,c'$ the successive places of the wave crest in successive equal intervals of time, 1, 2, 3, 4, 5, 6, 7, 8, 9, successive versed sines on $c\,d$ and $c'\,d'$ of equal arcs of the wave circle. When the wave centre is at C, the particle is at d'. When the wave centre is at e, the particle has risen to 1. When the wave centre has reached f, the water particle has risen to 2. When the wave has advanced to $g\,h\,c'$, &c., the water particle has risen to 3, 4, 5, &c.; and if every successive particle along the surface be conceived to perform successively a similar series of vertical motions, the surface of the water will present to the eye the visible moving wave form. Such is the simplest geometrical mode of exhibiting to the eye and of conceiving wave motion of the first order; it approximately represents the form of a wave of the first order whose height is small.

Horizontal Motion of each Particle.—This mode of representing the wave motion is inaccurate, in so far as it does not take account of the horizontal motion, which must of necessity accompany the vertical elevation of the water. Water being an inelastic fluid, any vertical column of the liquid can only have its length increased by a diminution of its horizontal dimension. It is necessary, therefore, to represent or conceive this horizontal motion as well as the vertical motion.

The horizontal range of motion of the wave is necessarily determined by the volume of the wave. The water which forms the wave is added to the given volume in which the wave is formed, at its posterior extremity, and thence displaces a new volume of water which goes to displace the volume of the wave in the next portion of the channel. Thus the volume of water which occupied the space A′ B′ b d before the transit of the wave (see Plate LII. fig. 4), occupies only the length A B b d during the wave transit, and it now consists of the rectangle A B $b\,d$, together with the volume of the wave A C d, which volume is equal to the volume A B B′ A′ by which it is replaced; and this happens successively in every point of the fluid. The horizontal range of motion is thus equal to the volume of water employed to form the wave.

While, therefore, the front of the wave is transmitted from A′ to *d*, the water particle A′ is transferred to A. The same particle is also raised and depressed through the height of the wave. These motions in the vertical and horizontal plane are simultaneous. It is required to represent accurately these motions: take $c\,d =$ the height of the wave, $A\,A' =$ the range of translation: describe an ellipse whose major axis is the range of translation, and whose semi-minor axis is the height of the wave: describe the wave circle *d* 1, 2, 3, 4, *c*, and having divided as formerly its circumference into equal parts, draw the horizontal ordinates 11, 22, 33, 44, &c., as in fig. 3, and let the curve of versed sines A′ C′ *d* be drawn as in fig. 3, then will the curve A′ 8, 7, 6, C′ 4, 3, 2, 1, *d*, represent the wave curve, the vertical motion only being considered. But at the same time that the particle rises and falls through 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 on the diameter *c d*, and in the curve of versed sines, the particle A′ will advance to A, through A′ 1, 2, 3, 4, 5, 6, 7, 8, 9, A. Thus every point in the curve will have to be advanced forward in the direction of translation in order to represent the actual form of the wave. This is done in fig. 4, and also for a larger wave in fig. 5. While the wave rises to 1, 2, 3, 4, C′, &c., it also advances simultaneously at each point by the quantity A′ 1, A′ 2, A′ 3, A′ 4, A′ 5, A′ 6, A′ 7, &c., and thus the wave A′ C′ *d* becomes transformed in both figures into A C *d*. This curve represents the form of the wave as corrected for the horizontal translation. Thus are reconciled to each other the apparently diverse motions of the particle, by one of which it describes the observed sinuous wave surface, and by the other the semiellipse of its path of translation.

Finally, as the motions of translation are equal and simultaneous throughout all particles situated in the same vertical line, the path of translation of each particle is an ellipse having the same major axis with that of the particle on the surface, but having its minor axis less in proportion to its distance from the surface of the liquid in repose. (See Plate XLVII. fig. 5.)

Hence, when the wave is not large, the amplitude of the particle path or range of translation is 3·1416 times the height of the wave; this quantity gradually diminishes as the height increases, and becomes nearly 2· when the height approaches the limit of equality with the height of the wave. But near this limit it is not capable of accurate observation.

Mechanism of the Wave.—The study of the phænomena of the translation of water particles during the transit of a wave is peculiarly valuable, as affording us the means of correctly conceiving the real nature of wave transmission of the first order; it therefore deserves great attention.

We perceive, in the first place, that the vertical arrangement of the water particles is not deranged by wave transmission; that is, if we conceive the whole fluid in repose to be intersected by transverse vertical planes, thin, and of the specific gravity of water, these planes will retain their parallelism during transmission and will not affect that transmission.

We may therefore accurately conceive the whole volume of water as reposing in rectangular vessels, each of them formed between two successive vertical thin moveable planes, and bounded by the two sides and bottom of the channel, and above by the plane of repose. The water in each of these elementary vessels undergoes in successive instances the same change as each of the others preceding it, and therefore we may direct our attention to one individual among them.

Let us study the manner in which wave motion is originally communicated to and through each of these elementary columns of fluid.

For this purpose it may be well to recur to the original mode of wave genesis (Plate XLVII. fig. 5.). A vertical generating plane P is inserted in the fluid, and forms one of the vertical boundaries of one of the elementary water columns. $\genfrac{}{}{0pt}{}{ab}{\alpha\beta}$ $\genfrac{}{}{0pt}{}{bc}{\beta\gamma}$ $\genfrac{}{}{0pt}{}{cd}{\gamma\delta}$ $\genfrac{}{}{0pt}{}{de}{\delta\varepsilon}$ $\genfrac{}{}{0pt}{}{ef}{\varepsilon\zeta}$ $\genfrac{}{}{0pt}{}{fg}{\zeta\theta}$ $\genfrac{}{}{0pt}{}{gh}{\eta\theta}$ &c. A moving force is applied to P, and the plane communicates to the water column $\genfrac{}{}{0pt}{}{ab}{\alpha\beta}$ that pressure; now this water column is bounded on its anterior surface by a similar vertical plane (of water particles) $\genfrac{}{}{0pt}{}{b}{\beta}$ in a state of rest, and the effect of this pressure is twofold, to raise the water column above the level to the height due to the velocity of P, and to diminish the breadth of the column in proportion to the increase of length. Such is the immediate effect of pressure on the plane P. Let us now consider the second (water) plane $\genfrac{}{}{0pt}{}{b}{\beta}$; it has now behind it a column of water pressing it forward with a velocity due to its height above the level of repose: it is therefore pressed forward, *à tergo*, just as the plane P originally was pressed forward, only its moving force is measured by the pressure of the column $\genfrac{}{}{0pt}{}{ab}{\alpha\beta}$ with a given height above the plane of repose. In all respects the water column $\genfrac{}{}{0pt}{}{bc}{\beta\gamma}$ is now in the condition which in the previous moment we found the column $\genfrac{}{}{0pt}{}{ab}{\alpha\beta}$. Let us now return to $\genfrac{}{}{0pt}{}{ab}{\alpha\beta}$ which is pressed by the plane P with a pressure not only equal to that which raised it to its former height, but with an accelerating force which raises it still higher, and communicates to it a velocity due to that greater height, and also diminishes its breadth in proportion to the increment in height. This new height in the column $\genfrac{}{}{0pt}{}{ab}{\alpha\beta}$ is a new increment of pressure on the vertical water plane $\genfrac{}{}{0pt}{}{b}{\beta}$, which in its turn presses the water column $\genfrac{}{}{0pt}{}{bc}{\beta\gamma}$ in the same manner, with a pressure due to the new height of the water column $\genfrac{}{}{0pt}{}{ab}{\alpha\beta}$, raises its height to that due to this pressure, and gives it a corresponding velocity. The third water column $\genfrac{}{}{0pt}{}{cd}{\gamma\delta}$ is now in similar circumstances to those of its predecessor $\genfrac{}{}{0pt}{}{bc}{\beta\gamma}$ at the preceding instant of time, and is pressed by the plane $\genfrac{}{}{0pt}{}{c}{\gamma}$ with a force due to the height of $\genfrac{}{}{0pt}{}{bc}{\beta\gamma}$, and the plane $\genfrac{}{}{0pt}{}{c}{\gamma}$ now moves forward, raises the height of $\genfrac{}{}{0pt}{}{cd}{\gamma\delta}$, and diminishes proportionally its breadth. The same process continues during the acceleration of the original plane P until it ceases to be further accelerated, and now the whole anterior half of the wave has been generated, and the column $\genfrac{}{}{0pt}{}{ab}{\alpha\beta}$ is moving with the velocity due to its elevation above the level, or the height due to the crest of the wave, having passed successively through each of the successive conditions of the columns before it. The force acting on P, *à tergo*, is now to be diminished; the pressure back upon its surface, arising from the height of $\frac{ab}{\alpha\beta}$, tends to retard the motion of P, and as the accelerating force is diminished the retardation increases, the whole action of the column $\frac{ab}{\alpha\beta}$ being continually to retard the plane P; and if the diminution of force take place in the same succession as the original increments, the diminution of the velocity of P will take place in a manner similar to that of its original increase, and it will finally be brought to rest when the column $\frac{ab}{\alpha\beta}$ has regained its level.

The same succession of conditions takes place in the plane which separates any two successive elementary columns; first of all the posterior surface of the plane is pressed by a higher column than itself, tending to increase its height and increased volocity, and having reached the maximum, the anterior surface is thereafter pressed by a water column of greater height than the posterior surface, retarding its velocity, and finally bringing it into a state of rest. Thus the forces and motion of each elementary plane are repetitions of the forces and motions of the original disturbing plane by which the wave was generated.

The power employed in wave genesis is therefore expended in raising to a height equal to the crest of the wave, each successive water column; each water column, again descending, gives out that measure of power to the next in succession, which it thus raises to its own height. The time employed in raising a given column to this height, and in its descent and communication of its own motion to the next in succession, constitutes the period of a wave, and the number of such columns undergoing different stages of the process at the same time measures the length of a wave.

During the anterior half of the wave the following processes take place. The generating force communicates to the adjacent column through its posterior bounding plane, a pressure; this pressure moves the posterior plane forward, the water in the column is thereby raised to the height due to the velocity, and the pressure of this water column communicates to the anterior bounding plane also a velocity and a pressure in the same direction; therefore the accelerating force produces a given motion of translation in the whole column a height of column due to that velocity, and an approximation of the anterior forces of the column to each other; these are all the forces and the motions concerned in the matter. The motive power thus stored during the anterior half of the wave is restored in the latter half wave length thus: the column raised to its greatest height presses on both its posterior and anterior surface, on the anterior surface it presses forward the anterior column, tending to sustain its velocity and maintain its height; on the posterior column its pressure tends to oppose the progress and retard the velocity of the fluid in motion, and thus retarding the posterior and accelerating the anterior surface, widens the space between its own bounding planes until it repose once more on the original level.

The Wave a Vehicle of Power.—The wave is thus a receptacle of moving power, of the power required to raise a given volume of water from its place in the channel to its place in the wave, and is ready to transmit that power through any distance along that channel with great velocity, and to replace it at the end of its path. In doing this the motion of the water is simple and easily understood, each column is diminished in horizontal dimension and increased proportionally in vertical dimension, and again suffered to regain its original shape by the action of gravity. There is no transference of individual particles through, between and amongst one another, so as to produce collisions, or any other motions which impair moving force; the particles simply glide for the moment over each other into a new arrangement, and retire back to their places. Thus the wave resembles that which we may conceive to pass along an elastic column, each slice of which is squeezed into a thinner slice, and restored by its elastic force to its original bulk, only in the water wave the force which restores the force of each water column is gravity, not elasticity.

To conceive accurately of the forces which operate in wave transmission, and of the *modus operandi*, to understand how the primary moving force acts on the column of fluid in repose, how this force is distributed among the particles, to distinguish the relative and absolute motions of the particles and the nature of the transmission of the form, and to understand how the force operates in at once propagating itself and restoring completely to rest those particles which form the vehicle of its transmission, is a study of much interest to the philosopher. To show how under a given form and outline of wave, in a given time, all and each of the individual particles of water obeying every one its own impulse and that of those around it, and subject to the laws of gravity and of the original impulse, shall describe its own path without interfering with another's, and shall unite in the production of an aggregate motion consistent with the continuity of the mass and with the laws of fluid pressure,—this is a problem which belongs to the mathematician, which has hitherto proved too arduous for the human intellect, and which we have thus endeavoured to facilitate and promote by the study of the absolute forms and phænomena of the waves themselves, and by the determination of the actual paths and motions of the individual particles of water.

The Negative Wave of the First Order.—The negative wave is a phænomenon whose place among waves it is somewhat difficult to assign. Its phænomena partake of those of the first order. But in its genesis and propagation it is always attended by a train of following phænomena of the second order.

The genesis of the negative wave of the first order is effected under conditions precisely the reverse of those of the positive wave. A solid body, Q_2 Q_3 (Plate LII. figs. 7, 8), is withdrawn from the water of the reservoir at one extremity, a cavity is created, and this cavity, W_1, is propagated along the surface of the water under a defined figure.

The velocity of the negative wave in a shallow channel is nearly that which is due to the depth calculated from the lowest part of the wave (as in the positive from the highest), but in longer waves it is sensibly less than that velocity. In Plate XLVIII. fig. 5 the observations are compared with this formula, from which they exhibit considerable deviations. Table XI. is a collection of negative waves observed in a small rectangular channel, and Table XII. contains others made in a triangular channel, both being made under the same conditions as the positive waves already given.

TABLE XI.

Observations on the Velocity of Negative Waves of the First Order.—In a rectangular channel 12 *inches wide.*

Col. A is the depth of the fluid reckoned in inches from the lowest point of the wave.

Col. B is the depth of the wave reckoned below the surface of repose.

Col. C is the number of seconds observed while the wave described the space given in column D in feet.

Col. E is the resulting velocity.

Col. F gives the velocities due to the depth, calculated by the formula $c = \sqrt{g(h-k)}$.

Col. G are the differences between observation and the formula.

A.	B.	C.	D.	E.	F.	G.
·915	—·085	9·0	14·62	1·62	1·56	— ·06
·925	—·075	9·5	14·62	1·53	1·57	+ ·04
·93	—·07	16·5	21·08	1·27	1·58	+ ·31
·935	—·065	12·0	20·0	1·66′	1·58	— ·08
·96	—·04	14·5	20·0	1·38	1·60	+ ·22
·965	—·035	15·0	21·08	1·40	1·60	+ ·20
·97	—·03	14·0	20·5	1·46	1·61	+ ·15
1·0					1·63	
2·0					2·31	
3·0					2·83	
3·3	—·8	5·5	14·62	2·65	2·97	+ ·32
3·4	—·7	6·0	14·62	2·43	3·02	+ ·59
3·495	—·605	8·0	21·08	2·63	3·08	+ ·45
3·603	—·497	13·5	41·08	3·04	3·10	+ ·06
3·71	—·39	6·5	20·0	3·07	3·15	+ ·08
3·745	—·355	7·0	20·0	2·85	3·16	+ ·31
3·77	—·33	10·83′	33·3′	3·07	3·18	+ ·11
4·0					3·27	
4·365	—·735	4·25	14·62	3·44	4·42	— ·02
4·575	—·525	6·0	20·0	3·33′	3·50	+ ·17
4·6	—·5	6·25	21·08	3·37	3·51	+ ·14
4·625	—·475	7·5	20·0	2·66	3·52	+ ·86
4·75	—·35	5·25	20·0	3·81	3·57	— ·24
5·0					3·66	
6·0					4·01	
7·0					4·33	
						+4·01
						—0·40
						+3·61
					Mean	+0·19

Table XII.

Observations on the Velocity of Negative Waves of the First Order.—In a triangular channel with sides sloping at 45°.

Cols. A, B, C, D, E, F and G, as in the preceding table.

Col. H is the ratio of defective velocity on the whole.

Col. F″ is taken, not from the formula like F, but from observed positive waves in the same channel of the same height.

Col. G″ contains the differences between F″ and E.

A.	B.	C.	D.	E.	F.	G.	H.	F″.	G″.
8·7	−0·7	29·8	100·	3·35	3·41	+ ·06	·0179	3·27	− ·08
8·8	−0·6	92·4	315·5	3·41	3·43	+ ·02	·0058	3·31	− ·10
8·9	−0·5	62·8	215·5	3·43	4·45	+ ·02	·0058	3·35	− ·08
9·0					3·47				
10·0					3·66				
11·0					3·84				
11·6	−0·9	29·2	100·	3·41	3·94	+ ·53	·1554	3·78	+ ·37
12·0					4·01				
13·0					4·17				
14·0					4·33				
15·0					4·48				
16·0					4·63				
16·8	−1·7	22·2	100·	4·50	4·74	+ ·24	·0533	4·50	·00
17·0	−1·5	22·0	100·	4·54	4·77	+ ·23	·0506	4·55	+ ·01
17·4	−1·1	21·6	100·	4·62	4·83	+ ·21	·0454	4·67	+ ·05
18·0	−0·5	21·6	100·	4·62	4·91	+ ·29	·0627	4·84	+ ·22
19·0					5·04				
20·0					5·18				
21·0					5·30				
22·0					5·43				
23·0					5·55				
24·0					5·67				
24·5	−1·5	19·0	100·	5·26	5·73	+ ·47	·0893	5·55	+ ·29
24·7	−1·3	18·9	100·	5·29	5·75	+ ·46	·0869	5·60	+ ·31
24·8	−1·2	18·6	100·	5·38	5·76	+ ·38	·0706	5·62	+ ·24
25·0	−1·0	18·6	100·	5·38	5·78	+ ·40	·0743	5·67	+ ·29
						+3·31	·7180		+1·78
					Mean	+0·275	·0598	Mean	− ·26
									+1·52
								Mean	+ ·126

The horizontal translation of water particles in the negative wave presents considerable resemblance to the corresponding phænomenon in the positive wave. All the particles of water in a given vertical plane move simultaneously with equal velocities backwards in the opposite direction to the transmission, and repose in their new planes, at the end of the translation; with this modification, however, that this state of repose is much disturbed near the surface by those secondary waves which follow the negative wave, but which do not sensibly agitate the particles considerably removed from the surface. (See Plate LII. fig. 9.) The path is the ellipse of the positive wave inverted.

The following measures may be useful. In a rectangular channel 4 inches deep in repose and 8 inches wide, a volume of 72 cubic inches is withdrawn; the depth of the negative wave below the plane of repose is $\frac{3}{8}$ths of an inch deep, the translation throughout the lower half-depth is $2\frac{1}{4}$ inches, and diminishes from the half-depths upwards, settling finally at the surface at $1\frac{3}{4}$ inch from the original position of the superficial particle.

The form of surface of the anterior half of the negative wave resembles closely the posterior half of a positive wave of equal depth, but the posterior half of the negative wave passes off into the anterior form of a secondary wave which follows it.

After translation the superficial particles continue to oscillate, as shown in Plate LII. figs. 9, 10, in the manner hereafter to be described, as a phænomenon of the train of secondary waves.

The characteristics of this species of wave of the first order are,—

(1.) That it is negative or wholly below the level of repose.

(2.) That it is a wave of translation, the direction of which is opposite to the direction of transmission.

(3.) That its anterior form is that of the positive wave reversed.

(4.) That the path of translation is nearly that of the positive wave reversed.

(5.) That its velocity is, in considerable depths, sensibly less than that due by gravity to half the depth reckoned from the lowest point, or the velocity of a positive wave being the same total height.

(6.) That it is not solitary, but always carries a train of secondary waves.

It is important to notice that the positive and negative waves do not stand to each other in the relation of companion phænomena. They cannot be considered in any case as the positive and negative portions of the same phænomena, for the following reasons:—

(1.) If an attempt be made to generate or propagate them in such manner that the one shall be companion to the other, they will not continue together, but immediately and spontaneously separate.

(2.) If a positive wave be generated in a given channel and a negative wave behind it, the positive wave moving with the greater velocity, rapidly separates itself from the other, leaving it far behind.

(3.) If a positive wave be generated and transmitted behind a negative wave, it will overtake and pass it.

(4.) Waves of the secondary class which consist of companion halves, one part positive and the other negative, have this peculiarity, that the positive and negative parts may be transmitted across and over each other without preventing in any way their permanence or their continued propagation. It is not so with the positive and negative waves of the first order.

(5.) If a positive and negative wave of equal volume meet in opposite directions, they neutralize each other and both cease to exist.

(6.) If a positive wave overtake a negative wave of equal volume, they also neutralize each other and cease to exist.

(7.) If either be larger, the remainder is propagated as a wave of the larger class.

(8.) Thus it is nowhere to be observed that the positive and negative wave coexist as companion phænomena.

These observations are of importance for this reason, that it has been supposed by a distinguished philosopher that the positive and the negative wave might be corresponding halves of some given or supposed wave.

On some Conditions which affect the Phænomena of the Wave of the First Order.—It has not appeared in any observations I have been able to make on the subject, that the wave of the first order retains the stamp of the many peculiarities that may be conceived to affect its origin. In this respect it is apparently different from the waves of sound or of colour, which bear to the ear and the eye distinct indications of many peculiarities of their original exciting cause, and thus enable us to judge of the character of the distant cause which emitted the sound or sent forth the coloured ray. It is not possible always to form an accurate judgement from the phænomena of the wave of the first order, of the nature of the disturbing cause, except in peculiar and small number of cases.

I have not found that waves generated by impulse by a fluid column of given and very various dimension, by immersion of a solid body of given figure, by motion in given velocity or in different directions; I have not found in the wave obtained by any of the many means any peculiarity, any variation either of form or velocity, indicating the peculiarity of the original. In one respect therefore the wave of translation resembles the sound wave; that all waves travel with the velocity due to half the depth, whatever be the nature of their source.

In one respect alone does the origin of the wave affect its history. Its volume depends on the quantity of power employed in its genesis, and on the distance through which it has travelled. A great and a little wave at equal distances from the source of disturbance, arise from great or little causes, but it is impossible to distinguish between a small wave which has travelled a short distance, and one which, originally high, has traversed a long space.

This however does not apply to compound waves of the first order, hereafter to be examined.

Form of Channel.—Its Effect on the Wave of Translation.—The conditions which affect the phænomena of the wave of translation are therefore to be looked for in its actual circumstances at the time of observation rather than in its history. The form and magnitude of the channel are among the most important of these circumstances. Thus a change in depth of channel immediately becomes indicated to the eye of the observer by the retardation of the wave, which begins to move with the same velocity as if the channel were everywhere of the diminished depth, that is, with the velocity due to the depth. Thus in a rectangular channel $4\frac{1}{2}$ feet deep, the wave moves with a velocity of 12 feet per second, and if the channel become shallower, so as to have only 2 feet depth, the change of depth is indicated by the velocity of the wave, which is observed now to move only with the velocity of 8 feet per second; but if the channel again change and become 8 feet deep, the wave indicates the change by suddenly changing to a velocity of 16 feet per second.

Length of Wave an Index of Depth.—In like manner, a wave which in water 4 feet deep is about 8 yards long, shortens on coming to a depth of 2 feet to a length of 4 yards, and extends itself to 16 yards long on getting into a depth of 8 feet. This extension of length is attended with a diminution of height, and the diminution of length with an increase of height of the wave, so that the change of length and height attend and indicate changes of depth.

In a rectangular channel whose depth gradually slopes until it becomes nothing, like the beach of a sea, these phænomena are very distinctly visible; the wave is first retarded by the diminution of depth, shortens and increases in height, and finally breaks when its height approaches to equality with the depth of the water. The limit of height of a wave of the first order is therefore a height above the bottom of the channel equal to double the depth of the water in repose. If we reckon the velocity of transmission as that due to half the total depth, and the velocity of translation as that due to the height of the wave, it is manifest that when the height is equal to the depth these two are equal, but that if the height were greater than this, the velocity of individual particles at the crest of the wave would exceed the velocity of the wave form; here accordingly the wave ceases, the particles in the ridge of the wave pass forward out of the wave, fall over, and the wave becomes a surge or broken foam, a disintegrated heap of water particles, having lost all continuity.

In like manner does the gradual narrowing of the channel affect the form and velocity of the wave, but its effects are by no means so striking as where the depth is diminished. The narrowing of the channel increases the height of the wave, and the effect of this is most apparent when the height is considerable in proportion to the depth; the velocity of the wave increases in proportion as the increase of height of the wave increases the total depth; but with this increase of depth, the length of the wave also increases rapidly, and it does not break so early as in the case of the shallowing of the water. Its phænomena are only visibly affected to the extent in which a change of depth is produced in the channel, by the volume of water added to the channel taking the velocity and form peculiar to that increased depth.

Table XIII.

Observed Heights of a Wave in Channel of variable Breadth.—Depth 4 *inches.*

	A. Breadth 12 in. Height of wave. in.	B. Breadth 6 in. Height of wave. in.	C. Breadth 3 in. Height of wave. in.
I.	2·0	2·4	3·3
II.	2·0	2·4	3·6
III.	2·0	2·55	3·3
IV.	1·5	2·5	3·5
V.	1·5	2·35	3·25
VI.	1·25	2·0	2·5
VII.	1·0	1·3	2·0
VIII.	0·25	0·3	0·4

These numbers appear to indicate that the increase of height does not widely differ from the hypothesis, that the height of a given wave in a channel of variable width is inversely as the square root of the breadth.

Thus, the inverse square roots of the breadths are as 1·73, 2·45 and 3·47, and the mean heights of the first five experiments are 1·8 2·45 3·39.

In the first five experiments the velocity observed was 4·25 feet per second. The velocity due by gravity to half the total depth 4 + 2·45 inches is 4·15 feet per second; and as the range of the wave was only 17 feet, and the time was only observed to half-seconds, these numbers coincide well enough to bear the conclusion that the velocity does not considerably differ from that due to the wave of the same mean height in a parallel channel of the same depth.

Table XIV.

Observations in a Channel of variable Depth.—Diminution of depth from 4 *inches to* 0· *in a length of* 17 *feet.*

	A. Height of wave in a depth of 4 in. in.	B. Height of wave breaking in depth (C). in.	C. Depth of water where wave (B) broke. in.	D. Time of traversing 17 ft. s.	E. Velocity in feet per sec.
I.	4·0*	4·0*	4·0	5·5	3·09
II.	3·7*	3·7*	3·7	5·5	3·09
III.	3·4*	3·4*	3·4	5·5	3·09
IV.	2·5	2·7	2·7	5·5	3·09
V.	2·0	2·4	2·4	5·5	3·09
VI.	1·8	2·2	2·2	5·5	3·09
VII.	1·5	2·0	2·1		
VIII.	1·3	1·9	1·9		
IX.	1·25	1·9	1·9		
X.	1·2	1·7	1·7		
XI.	1·1	1·4	1·4	6·0	2·83
XII.	1·0	1·2	1·2		
XIII.	0·8	0·8	1·1	6·5	2·6
XIV.	0·5	0·7	0·9	7·0	2·4
XV.	0·2*	0·2*	0·2	7·5	2·0

Hence we find that the numbers representing depths in column C may be regarded as the limits of those in column B, that the depth of the fluid below the level of repose is equal to the greatest height which a wave can attain at that point, and at that height the wave breaks.

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* These numbers are interpolated; the numbers in column D are waves not observed on the identical waves in the first three columns, but are others of nearly equal heights, in identical conditions.

The time occupied by the largest class of wave is 5·5 seconds, and the corresponding *mean* velocity is 3·09 feet per second; this is the velocity due to a depth of 3·6 inches, but the depth total at the one end of the channel is nearly double this quantity, diminishing to 0 at the end. The time in which the wave in a shelving channel passes along the whole length, is therefore nearly equal to the time in which a wave would travel the same distance if the channel were uniformly of a depth equal to the mean depth of the channel, reckoning in both cases from the top of the wave. In these cases the height of the wave is large. Let us take a small height of wave as Ex. XIV.; there we have also in this case the mean depth reckoned from the top of the wave $=2\cdot2$, the velocity in a channel of that uniform depth $=2\cdot4$, and the time $7^{s}\cdot08$. These experiments are sufficiently accurately represented if we take for the velocity of the wave in the sloping channel that of a wave in a channel having a uniform depth equal to the mean depth of the channel, reckoned as usual from the top of the wave.

If therefore we are to calculate the time in which a wave will traverse a given distance q, to the limit of the standing water-line, after it has begun to break on a sloping beach, we have, the height at breaking being $h=$ the standing depth of the water at the breaking-point,

$$t=\frac{q}{\sqrt{g(h+k)}} \text{ and } v=\sqrt{g(h+k)}.$$

Ex. A wave 3 feet high breaking in water 3 feet deep, on a sloping shore at a distance of 60 feet from the edge of the water, would traverse that space in about 6 seconds, for

$$t=\frac{60}{32\cdot3\sqrt{}}=\frac{60}{9\cdot82}=6 \text{ seconds nearly.}$$

By repeated observations I have ascertained that waves break whenever their height above the level of repose becomes equal very nearly to the depth of the water.

The gradual retardation of the velocity of waves breaking on a sloping beach, as they come into shallower water, is rendered manifest in the closer approximation of the waves to each other as they come near the margin of the water. Vide *et seq.*

It may be observed also that the height of the wave does increase, but very slowly (before breaking), as the depth diminishes; thus in VII., a height of 1·8 in a depth of 4 inches becomes 2·2 in 2 inches depth, and in XII. a height of 1 inch in a depth of 4 inches becomes a depth of 1·2 inch only 1·2 inch high. The increase of height is therefore very much slower than the inverse ratio of the depth, or than the inverse ratio of the square of the depth.

Form of Transverse Section of Channel.—We have seen that in a given rectangular channel, the volume of the wave, its height and the depth being given, no peculiarity of origin or other condition sensibly affects its actual phænomena. But it becomes of importance to know whether the form of a given channel, its volume being given, will affect the phænomena of the wave of the first order; for example, whether in a channel which is semicircular on the bottom, or triangular, but holding a given quantity of water, the wave would be affected by the form of the channel, the volume or cross section remaining unchanged.

Considering this question *à priori*, we might form various anticipations. We might expect in a channel in which the depth of transverse section varies, that as its depth is greatest at one point, suppose the middle, and less at the sides, the wave might move with the velocity due to the middle or greatest depth; or we might expect that it would move with the velocity simply due to the mean depth, that is, with the same velocity as in a rectangular channel of a depth equal to the mean depth of the channel; or we might expect that each portion of the wave would move with a velocity due to the depth of that part of the channel immediately below each part of the wave, and so each part passing forward with a velocity of its own, have a series of waves, each propagating itself with an independent velocity, and speedily becoming diffused, and so a continued propagation of a wave in such circumstances would become *impossible* from disintegration; and instead of a single large wave we should have a great many little ones. Or, finally, we might have a perfect wave moving with a velocity, the mean of the velocities which each of these elementary waves might be supposed to possess.

I soon found that the propagation of a single wave, *i. e.* one of which all the parts should have a given common velocity, was *possible* in a channel whose depth at different breadths is variable; that the wave does not necessarily become disintegrated; that its parts do not move with the different velocities due to the different depths of the different parts of the channel, but that the entire wave does (with certain limits) move with such velocity as if propagated in a channel of a rectangular form, but of a less depth than the greatest depth of the channel of variable channel.

It became necessary therefore to determine the depth of a rectangular channel equivalent to the depth of a channel of variable transverse section; to determine, for example, in a channel of triangular section ▽, the depth of rectangular channel in which a wave would be propagated with equal velocity. In this case the simple arithmetical mean depth of the channel is *half of the depth in the middle.* But on the other hand, if we calculate the velocity due to each point of variable depth, and take the mean of these velocities, we shall find a mean velocity such as would be due to a wave in a rectangular channel *two-thirds of the greatest depth.*

In the first series of experiments I made on this subject, I conceived that the results coincided sufficiently well with the latter supposition; but they were on so small a scale, that the errors of observation exceeded in amount the differences between the quantities to be determined, and the results did not establish either. Mr. Kelland arrived at the opposite conclusion, his theoretical investigations indicating the former result. I examined the matter afresh, and after an extensive series of experiments, have established beyond all question the fact, that the velocity in a triangular channel is that due by gravity to one-fourth of the maximum depth. Although therefore the absolute velocity assigned by Mr. Kelland's investigations deviates widely from the true velocity, yet he has assigned the true relation between the velocities in the triangular and the rectangular channel; and if therefore we take the absolute velocity which I have determined for the rectangular channel, and deduce from it the relative velocity which Mr. Kelland has assigned to the triangular form, we obtain a number which is the true velocity of the wave in a ∇^r channel.

TABLE XV.

Observations on the Wave of the First Order in triangular Channels.

The sides of the channels are planes, and slope at an angle with the horizon = 45°.

Col. A is the observed depth of the channel in the middle, reckoned from the crest of the wave.

Col. B is the height of the wave taken as the mean between the observations at the beginning and end of the experiment.

Col. C is the observed time in seconds occupied by the wave in describing the distance in column D.

Col. D is the space in feet described by the wave during each observation.

Col. E is the velocity resulting from these observations.

Col. F is the velocity due by gravity to $\frac{1}{4}$ of the depth of the fluid, $v = \sqrt{\frac{1}{2} g (h + k)}$.

Col. G is the velocity due by gravity to $\frac{2}{3}$ of the depth of the fluid, $v = \sqrt{\frac{2}{3} g (h + k)}$.

Cols. H and K show the difference between Cols. F and G and the observations, and the result in favour of F.

A.	B.	C.	D.	E.	F.	G.	H.	K.
in.	in.							
4·15	0·15	36·5	80·0	2·19	2·35	2·72	+ ·16	+ ·53
4·23	0·22	33·0	80·0	2·42	2·38	2·75	− ·04	+ ·33
4·32	0·31	31·0	75·5	2·43	2·40	2·78	− ·03	+ ·35
4·38	0·37	47·0	115·5	2·46	2·42	2·79	− ·04	+ ·33
4·71	0·70	13·5	35·5	2·62	2·51	2·90	− ·11	+ ·28
4·81	0·80	29·5	75·5	2·57	2·54	2·93	− ·03	+ ·36
4·86	0·85	14·0	35·5	2·53	2·55	2·95	+ ·02	+ ·42
5·29	0·18	31·0	80·0	2·58	2·66	3·07	+ ·08	+ ·49
5·44	0·33	45·5	120·0	2·63	2·70	3·11	+ ·07	+ ·48
5·55	0·44	58·0	160·0	2·75	2·72	3·15	− ·03	+ ·40
5·59	0·48	30·0	80·0	2·66	2·73	3·16	+ ·07	+ ·50
5·99	0·88	12·0	35·5	2·95	2·83	3·27	− ·12	+ ·32
6·01	0·90	24·5	71·0	2·89	2·84	3·29	− ·05	+ ·40
6·18	0·14	28·0	80·0	2·85	2·87	3·32	+ ·02	+ ·47
6·26	0·21	55·5	160·0	2·88	2·89	3·34	+ ·01	+ ·46
6·38	0·34	14·0	40·0	2·85	2·92	3·37	+ ·07	+ ·52
6·44	1·33	12·0	35·5	2·95	2·93	3·39	− ·02	+ ·44
6·52	0·48	26·5	80·0	3·02	2·95	3·41	− ·07	+ ·39
6·78	0·74	35·0	111·0	3·17	3·01	3·48	− ·16	+ ·31
7·10	0·60	26·5	80·0	3·02	3·08	3·56	+ ·06	+ ·54
7·12	0·08	39·5	120·0	3·03	3·09	3·56	+ ·06	+ ·53
7·15	0·11	78·5	240·0	3·05	3·09	3·57	+ ·04	+ ·52
7·16	0·12	52·5	160·0	3·04	3·10	3·58	+ ·06	+ ·54
7·21	0·17	26·5	80·0	3·02	3·11	3·59	+ ·09	+ ·57
7·36	0·32	26·5	80·0	3·02	3·14	3·62	+ ·12	+ ·60
7·51	0·47	25·0	80·0	3·20	3·18	3·66	− ·02	+ ·46
7·53	0·47	24·0	80·0	3·33	3·17	3·67	− ·16	+ ·34
10·0	0·75	55·4	215·5	3·89	3·66	4·23	− ·23	+ ·34
10·5	1·1	41·94	166·0	3·95	3·75	4·33	− ·20	+ ·38
11·0	1·44	31·2	123·1	3·94	3·84	4·43	− ·10	+ ·49
14·5	2·0	48·36	215·5	4·45	4·41	5·09	− ·04	+ ·64
15·0	2·58	26·46	119·25	4·50	4·48	5·18	− ·02	+ ·68
15·5	3·1	22·2	100·0	4·50	4·56	5·26	+ ·06	+ ·76
19·0	0·35	19·8	100·0	5·06	5·04	5·83	− ·02	+ ·77
19·5	0·87	19·5	100·0	5·13	5·11	5·90	− ·02	+ ·77
20·0	1·35	25·66	138·5	5·40	5·18	5·98	− ·22	+ ·58
20·5	1·85	28·8	157·75	5·48	5·24	6·05	− ·24	+ ·57
21·0	2·36	24·93	138·5	5·55	5·30	6·13	− ·25	+ ·58
21·5	2·8	17·8	100·0	5·61	5·36	6·20	− ·25	+ ·59
26·0	1·5	35·8	215·5	6·02	5·90	6·82	− ·12	+ ·80
26·5	1·95	22·46	138·5	6·16	5·96	6·88	− ·20	+ ·72
27·0	2·12	20·7	128·87	6·22	6·01	6·95	− ·21	+ ·73
27·5	2·4	21·73	138·5	6·37	6·07	7·01	− ·30	+ ·64
28·0	3·12	20·45	128·75	6·29	6·13	7·07	− ·16	+ ·78
28·5	3·03	15·93	100·0	6·27	6·18	7·14	− ·09	+ ·87
29·0	3·02	15·8	100·0	6·33	6·23	7·20	− ·10	+ ·87
29·5	2·5	15·68	100·0	6·37	6·29	7·26	− ·08	+ ·89
30·0	2·77	15·6	100·0	6·41	6·34	7·32	− ·07	+ ·91
30·5	2·25	15·6	100·0	6·41	6·39	7·38	− ·02	+ ·97
31·0	2·5	15·8	100·0	6·33	6·44	7·44	+ ·11	+ 1·11
31·5	3·0	15·26	100·0	6·55	6·50	7·50	− ·05	+ ·95
							−2·77	+29·27

No great number of experiments has been made on channels of other forms of variable depth, such as have been made coinciding with those in the triangular channel, so far as to show that we may take the simple arithmetical mean depth as the depth of the rectangular channel of a wave of equal velocity, and so in general reckon the mean depth as

$$h=\frac{1}{x}\int y\,dx,$$

or $$v=\left(\frac{g}{x}\int y\,dx\right)^{\frac{1}{2}}.$$

The form of transverse section does not therefore affect the velocity of the wave otherwise than as it becomes necessary to use the mean depth as the argument in calculating it, and not the maximum depth.

The Form of Channel affects the Form of the Wave as well as its Velocity.—When the channel is very broad the wave ceases to have a velocity, it loses unity of character, and each part of it moves along the channel independent of the velocity of the other, and with the velocity due to the local depth of the channel. Where the water is shallow the wave becomes sensibly higher and shorter, and when the difference of depth is not considerable, the wave is found to increase in height so as to give in the shallow part a velocity equal to that in the narrow part. When the channel is narrow in proportion to its depth, this unity of propagation exists without sensible difference of velocity towards the side, and without very great difference in height at the sides. In a channel of the form of a right-angled and isosceles triangle, with the hypothenuse upwards and horizontal, it is visible to the eye that the wave is somewhat longer and lower in the middle, but higher and shorter at the sides, but that it retains most perfect unity of form and velocity, and moves along unbroken with the velocity due to the mean depth. The same figure with the angle at the bottom increased so that each side has a slope of one in four, still contains a single wave propagated with a single velocity, being that due to half the depth, but breaks at the shallow side, becoming disentegrated in form though not in velocity.

In a channel 12 inches wide, 5 inches deep on one side, and 1 inch deep on the other, the following observations were made:—

Height of the Wave.

Deep side. in.	Shallow side. in.
2·00	2·50
1·50	2·50
1·20	2·00
0·75	1·20
0·75	1·20
0·75	1·00
0·50	1·00
0·25	0·50
0·25	0·40
0·25	0·40

On the Incidence and Reflexion of the Wave of the First Order.—When a wave of the first order encounters a solid plane at right angles to the direction of its propagation, it is wholly reflected and is thrown back in the opposite direction with a velocity equal to that in which it was moving before impact, remaining in every respect unchanged, excepting in direction of motion. This process may be repeated any number of times without affecting any of the wave phænomena excepting the direction of motion.

When the angle which the ridge of the incident wave makes with the solid plane is small, that is, when the direction of propagation does not deviate much from the perpendicular to the plane, the wave undergoes total reflexion, and the angles of reflexion and of incidence are equal, as in the case of light.

When the deviation of the direction of propagation from the perpendicular is considerable, the reflexion ceases to be total. At 45° the reflected wave is sensibly less than the incident wave.

When the ridge of the wave is incident at about 60° from the plane surface, and the direction of the ridge only diverges about 30° from a perpendicular to the plane, reflexion ceases to be possible. A remarkable phænomenon is exhibited which I may be allowed to designate the *Lateral Accumulation* and *Non-Reflexion* of the wave. It is to be understood by considering the effect of supposed reflexion; this would be to double over upon itself a part of the wave moving in nearly the same direction; the motions of translation of the particles being compounded will give a resultant at right angles to the plane, and will also give a wave of greater magnitude and a translation of greater velocity. By these means accumulation of volume and advancement of the ridge in the vicinity of the obstacle take place; as represented in the diagram.

These phænomena are accurately represented in Plate LIII., as observed in a large shallow reservoir of water.

On the Lateral Diffusion and the Lateral Accumulation of the Wave of the First Order.—When a wave of the first order has been generated in a narrow channel, and is propagated into a wider one, it becomes of some importance to know whether and how this wave will affect the surface of the larger basin into which it is admitted. It is known that common surface waves of the second order diffuse themselves equably in concentric circles round the point of disturbance. How is the great primary wave diffused?

TABLE XVI.

Observations on the Lateral Diffusion of the Wave of the First Order, generated in a narrow Channel and transmitted into a wide Reservoir.

The apparatus employed for this purpose is exhibited in Plate LIV. figs. 1 and 2. T was a tank 20 feet square, filled to the depth of 4 inches; the chamber C, fig. 2, was 12 inches square, in which the wave was generated by impulse for the first five experiments, in all subsequent to which C was enlarged in width to 2 feet, as shown in fig. 1. The line marked A, figs. 1 and 2, was a wooden bar, in which were inserted at intervals of 6 inches, sharp pieces of pencil, projecting downwards to the surface of the water; the numbers of which, reckoning from the side of the tank outwards, are contained in the first vertical column of numerals, the Roman numerals in this table denoting the number of the experiment. The bar being placed parallel to the side of the tank at C, and distant from it 12 feet, consequently distant 9 feet from the mouth of the channel, whose length is 3 feet; the distance from its under edge to the surface of the still water was carefully measured, and when the wave had passed, and before its reflexion, the bar was removed, the distances from its under edge to the highest marks on the pencils were put down in column A of the table, and the absolute height of the wave itself, obtained by subtracting these figures from the statical level, was put down in column B.

In the diagrams, Plate LIV., the waves are laid down from the line A A, and at horizontal intervals of one-tenth of an inch, corresponding to the relative positions of the points at which they were observed. In figs. 1 and 2, an approximate mean is given of the waves generated in the large and small channels, each line at the bar A indicating a height of one-tenth part of an inch.

	I.		II.		III.		IV.		V.		VI.	
	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.
1	2·3	·375	2·15	·525	2·05	·625	2·1	·575	·8	·7	·3	1·2
2	2·4	·275	2·175	·5			2·15	·525	·85	·65	·4	1·1
3	2·45	·225	2·225	·45	2·15	·525	2·2	·475	·95	·575	·5	1·0
4	2·45	·225	2·2	·475	2·15	·525	2·15	·525	·8	·725	·4	1·225
5	2·45	·225	2·225	·45	2·15	·525	2·15	·525	·85	·675	·4	1·225
6	2·45	·225	2·3	·375	2·2	·475	2·2	·475	·925	·612	·45	1·075
7	2·475	·2	2·275	·4	2·2	·475	2·25	·425	·925	·625	·5	1·035
8	2·5	·175	2·35	·325	2·25	·425	2·275	·4	1·25	·5	·625	·925
9	2·55	·125	2·4	·275	2·3	·375	2·35	·325	1·05	·5	·625	·925
10	2·55	·125	2·35	·325	2·3	·375	2·3	·375	1·0	·55	·65	·9
11	2·6	·075	2·4	·275	2·3	·375	2·325	·35	1·1	·45	·7	·85
12	2·6	·075	2·425	·25	2·35	·325	2·375	·3	1·05	·512	·825	·75
13	2·6	·075	2·425	·25	2·35	·325	2·35	·325	1·075	·487	·8	·775
14	2·6	·075	2·45	·225	2·375	·3	2·4	·275	1·1	·487	·8	·775
15	2·65	·025	2·45	·225	2·375	·3	2·4	·275	1·1	·475	·9	·675
16	2·65	·025	2·45	·225	2·4	·275	2·4	·275	1·1	·475	·85	·735
17	2·65	·025	2·45	·225	2·4	·275	2·4	·275			·85	·75

This table shows in column B, how the height of the wave diminishes as it spreads out from the line of original direction in which it was generated. Lateral diffusion therefore takes place, but with a great diminution of height of the wave.

This phænomenon is of importance in reference especially to the law of diffusion of the tides, in such situations as where they enter the German Sea through the English Channel, and the Irish Sea through St. George's Channel. It enables us to account for the great inequality of tides in the same locality. It likewise furnishes an analogy by which we may explain some of the hitherto anomalous phænomena of sound.

Axis of Maximum Displacement of the Wave of the First Order.—That a wave of the first order, on entering a large sheet of water, does not diffuse itself equally in all directions around the place of disturbance (as do the waves of the second order produced by a stone dropped in a placid lake), but that there is in one direction *an axis* along which it maintains the greatest height, has the widest range of translation, and travels with greatest velocity, viz. in the direction of the original propagation as it emerged from the generating reservoir, is a phænomenon which I have further confirmed by a number of experiments. This phænomenon is of importance, especially if we take the wave of the first order, the same (as I think I have established) as type of the tide wave of the sea and of the sound wave of the atmosphere. I determined this in the simplest way. I filled a reservoir which has a smooth flat bottom and perpendicular sides some 20 feet square, to a depth of 4 inches with water. In a small generating reservoir only a foot wide, I generated a wave of the first order. A circle was drawn on the bottom of the large basin, and of course visible through the water, having its centre at the place of disturbance, and divided into arcs of 30°, 45°, 60° and 90°, on which observers were placed, and the heights of the same wave, as observed at the points, is given in the accompanying table.

TABLE XVII.

Observations on the Diffusion of the Wave of the First Order round an Axis of original Transmission.

The observations were made upon the wave at various points in circles of 9 and 15 feet radius, described from the outer extremity of the side of the channel C, as shown in Plate LIV. fig. 3. The depth of the water when at rest was taken at the various points, and these being subtracted from the absolute height to which the wave attained in its transit, gave the amounts which are contained in the lower part of the table, the absolute heights from which these are deduced being given immediately above in columns marked thus, A, B, C, D, E, while the deducted heights are distinguished thus, A′, B′, C′, D′, E′. Experiments VII. to XV. were made in the 9 feet circle, and the remainder in that of 15 feet radius. It will be observed that in the latter set there are two columns which are headed zero, but it must be remembered that the one in brackets contains observations which were made at the 9 feet distance along the axis and the remainder on the outer circle.

Fig. 3 contains the approximate ratio of the height of the wave at different points in the circumference of the circles expressed by lines concentric to the circles, each of which denotes the tenth part of an inch.

The observations are laid down accurately in the diagrams, where the lines A B and C D represent the circumference of the quadrants of the observed circles. Upon these lines the true heights of the wave are measured upwards at their respective points of observation, and a curve drawn through these, representing the mean of the wave's height. From these and from a numerical discussion of the observations, it appears that the height of the wave at 0° being 1, its height at the remaining points will be $\frac{1}{2}$, $\frac{2}{5}$, $\frac{1}{3}$, and $\frac{1}{10}$, or taking integral numbers to express the ratio, it will stand thus, 30, 15, 12, 10, 3. And from a discussion of the whole of the experiments it is found that the height of the wave is inversely as the distance from the centre.

Fig. 4 shows the appearance of the wave upon which these observations were made.

	A.	B.	C.	D.	E.		G.	H.	K.	L.	M.
	0°.	30°.	45°.	60°.	90°.		(0°.)	0°.	30°.	60°.	90°.
VII.	4·5		4·15		4·05	XVI.		4·25	4·3		4·4
VIII.	4·625		4·35		4·05	XVII.		4·125	4·5		
IX.	4·875		4·4		4·05	XVIII.		4·25	4·5		
X.	4·5	4·35			4·05	XIX.		4·25	4·4		
XI.	4·325	4·3			4·05	XX.		4·25	4·3		
XII.	4·5	4·3			4·05	XXI.		4·25		4·3	
XIII.	4·5	4·2				XXII.		4·375		4·3	
XIV.	4·75			4·3	4·05	XXIII.		4·1		4·3	
XV.	4·5			4·25	4·05	XXIV.		4·1		4·25	
	A′.	B′.	C′	D′.	E′.		G′.	H′.	K′.	L′.	M′.
VII.	1·0		·3		·1	XVI.		·75	·3		·1
VIII.	1·125		·5		·1	XVII.	·7	·625	·5		
IX.	1·375		·55		·1	XVIII.		·75	·5		
X.	1·0	·55			·1	XIX.		·75	·4		
XI.	·825	·5			·1	XX.	1·3	·75	·3		
XII.	1·0	·5			·1	XXI.	1·5	·75		·25	
XIII.	1·0	·4				XXII.		·875		·25	
XIV.	1·25			·4	·1	XXIII.	1·1	·6		·25	
XV.	1·0			·35	·1	XXIV.	1·15	·6		·2	

Thus it was determined that along the axis of maximum intensity, the height of the wave there being the greatest, there was a corresponding acceleration of the wave motion. On each side of this axis the magnitude of the wave diminishes rapidly, being at 30° diminished to $\frac{1}{2}$, and at 60° to $\frac{1}{3}$ of its height along the axis, and as this diminution was attended with a corresponding retardation of propagation, so the ridge of the wave became somewhat elliptical, having for its major axis the axis of maximum intensity of the wave. At right angles to the principal axis of propagation the wave is scarcely sensible, a height of one-tenth part of that in the axis being the greatest that was observed; and that indeed was, in the circumstances of observation, scarcely sensible.

Concluding Remarks and Application.—There are several great applications of our knowledge of waves of the first order, which give value to that knowledge beyond that which belongs to truth for its own sake. The phænomena of the wave of translation are so beautiful and regular, that as a study of nature it possesses a high interest. The velocity of the wave is one of the great constants of nature, and is to the phænomena of fluids what the pendulum is to solids, a connecting link between time and force; as a phænomenon of hydrodynamics, it furnishes one of the most elegant and interesting exercises in the calculus of the wave mathematics.

But besides its importance in these aspects, there are others in which it is capable of being regarded, each of which gives it value both in art and in science:—

1. The wave of the first order is to be regarded as a vehicle for the transmission of mechanical force (geological application).

2. The wave of the first order is an important element in the calculation and phænomena of resistance of fluids (form of ships, canals, &c.).

3. The wave of the first order is identical with the great oceanic wave of the tide (improvement of tidal rivers).

4. The water-wave of the first order presents some analogy to the sound wave of the atmosphere (phænomena of acoustics).

TABLE XVIII.

The Velocity of the Wave of the First Order, calculated for various depths of the fluid in a channel of uniform depth, extending a depth from 0·1 of an inch to 100 feet.

Column A contains the depths of the fluid in decimal parts of an inch.
Column B the corresponding velocities in feet per second.
Column C gives the depth in inches.
Column D the corresponding velocities in feet per second.
Column F gives the depths in feet.
Column G the corresponding velocities in feet per second.
Columns of Differences, E and H, will assist in extending the table.

A. Value of $h+c$ in inches.	B. Value of $\sqrt{g(c+h)}$ in feet per sec.	C. Value of $h+c$ in inches.	D. Value of $\sqrt{g(c+h)}$ in feet per sec.	E. First difference.	F. Value of $h+c$ in feet.	G. Value of $\sqrt{g(c+h)}$ in feet per sec.	H. First difference.
0·0	0·0000	0·0	0·000		0·0	0·000	
·1	0·5179	1·0	1·637		1·0	5·674	
·2	0·7325	2·0	2·316		2·0	8·024	
·3	0·8971	3·0	2·836		3·0	9·827	
·4	1·0359	4·0	3·275		4·0	11·347	
·5	1·1581	5·0	3·662		5·0	12·687	
·6	1·2687	6·0	4·011		6·0	13·898	
·7	1·3703	7·0	4·333		7·0	15·011	
·8	1·4649	8·0	4·632		8·0	16·047	
·9	1·5538	9·0	4·913		9·0	17·021	
1·0	1·6378	10·0	5·179		10·0	17·942	
·1	1·7178	11·0	5·432	253	11·0	18·817	875
·2	1·7942	I. 12·0	5·673	241	12·0	19·654	837
·3	1·8674	13·0	5·905	231	13·0	20·457	803
·4	1·9379	14·0	6·128	222	14·0	21·229	772
·5	2·0060	15·0	6·343	215	15·0	21·974	745
·6	2·0717	16·0	6·551	207	16·0	22·695	721
·7	2·1355	17·0	6·753	201	17·0	23·393	698
·8	2·1974	18·0	6·948	195	18·0	24·071	678
·9	2·2576	19·0	7·139	190	19·0	24·731	660
2·0	2·3163	20·0	7·324	185	20·0	25·374	643
·1	2·3735	21·0	7·505	180	21·0	26·000	626
·2	2·4293	22·0	7·682	176	22·0	26·612	612
·3	2·4839	23·0	7·854	172	23·0	27·210	598
·4	2·5373	II. 24·0	8·023	168	24·0	27·796	586
·5	2·5896	25·0	8·189	165	25·0	28·368	572
·6	2·6409	26·0	8·351	162	26·0	28·930	562
·7	2·6913	27·0	8·510	159	27·0	29·481	551
·8	2·7405	28·0	8·666	156	28·0	30·023	542
·9	2·7891	29·0	8·820	153	29·0	30·554	531
3·0	2·8368	30·0	8·970	150	30·0	31·076	522
·1	2·8834	31·0	9·118	149	31·0	31·589	513
·2	2·9299	32·0	9·265	147	32·0	32·095	505
·3	2·9753	33·0	9·408	143	33·0	32·593	497
·4	3·0200	34·0	9·550	141	34·0	33·083	490
·5	3·0641	35·0	9·689	139	35·0	33·566	480
·6	3·1076	III. 36·0	9·827	137	36·0	34·042	476
·7	3·1505	37·0	9·962	135	37·0	34·512	470
·8	3·1928	38·0	10·096	133	38·0	34·976	464
·9	3·2337	39·0	10·228	131	39·0	35·434	458
4·0	3·2756	40·0	10·358	130	40·0	35·883	449
·1	3·3164	41·0	10·487	128	41·0	36·329	446
·2	3·3566	42·0	10·614	127	42·0	36·771	442
·3	3·3963	43·0	10·740	125	43·0	37·205	434
·4	3·4356	44·0	10·864	124	44·0	37·635	430
·5	3·4744	45·0	10·987	122	45·0	38·060	425
·6	3·5128	46·0	11·108	121	46·0	38·481	421
·7	3·5508	47·0	11·229	120	47·0	38·897	416
·8	3·5884	IV. 48·0	11·347	118	48·0	39·308	411
·9	3·6225	49·0	11·464	117	49·0	39·716	408
5·0	3·6623	50·0	11·581	116	50·0	40·119	403
·1	3·6988	51·0	11·696	115	51·0	40·518	399
·2	3·7348	52·0	11·810	114	52·0	40·913	395
·3	3·7704	53·0	11·923	113	53·0	41·304	391
·4	3·8056	54·0	12·035	112	54·0	41·693	389
·5	3·8405	55·0	12·146	111	55·0	42·079	386
·6	3·8758	56·0	12·256	110	56·0	42·458	379
·7	3·9101	57·0	12·365	109	57·0	42·834	376
·8	3·9441	58·0	12·473	108	58·0	43·209	375
·9	3·9778	59·0	12·580	107	59·0	43·580	371

Table XVIII. continued.

A. Value of $h+c$ in inches.	B. Value of $\sqrt{g(c+h)}$ in feet per sec.	C. Value of $h+c$ in inches.	D. Value of $\sqrt{g(c+h)}$ in feet per sec.	E. First difference.	F. Value of $h+c$ in feet.	G. Value of $\sqrt{g(c+h)}$ in feet per sec.	H. First difference.
6·0	4·0120	V. 60·0	12·686	106	60·0	43·948	368
·1	4·0451	61·0	12·791	105	61·0	44·315	367
·2	4·0779	62·0	12·895	104	62·0	44·678	363
·3	4·1105	63·0	12·998	103	63·0	45·037	359
·4	4·1434	64·0	13·101	103	64·0	45·392	355
·5	4·1755	65·0	13·203	102	65·0	45·745	353
·6	4·2074	66·0	13·305	102	66·0	46·095	350
·7	4·2390	67·0	13·406	101	67·0	46·442	347
·8	4·2710	68·0	13·506	100	68·0	46·786	344
·9	4·3021	69·0	13·605	99	69·0	47·127	341
7·0	4·3333	70·0	13·704	99	70·0	47·467	340
·1	4·3640	71·0	13·801	97	71·0	47·805	338
·2	4·3958	VI. 72·0	13·897	96	72·0	48·142	337
·3	4·4251	73·0	13·993	96	73·0	48·477	335
·4	4·4551	74·0	14·088	95	74·0	48·809	332
·5	4·4850	75·0	14·183	95	75·0	49·137	328
·6	4·5152	76·0	14·277	94	76·0	49·462	325
·7	4·5447	77·0	14·371	94	77·0	49·786	324
·8	4·5740	78·0	14·464	93	78·0	50·108	322
·9	4·6031	79·0	14·556	92	79·0	50·429	321
8·0	4·6325	80·0	14·648	92	80·0	50·748	319
·1	4·6612	81·0	14·739	91	81·0	51·061	317
·2	4·6898	82·0	14·830	91	82·0	51·376	315
·3	4·7182	83·0	14·921	91	83·0	51·689	313
·4	4·7470	VII. 84·0	15·011	90	84·0	52·000	311
·5	4·7761	85·0	15·100	89	85·0	52·309	309
·6	4·8040	86·0	15·189	89	86·0	52·616	307
·7	4·8318	87·0	15·277	88	87·0	52·921	305
·8	4·8586	88·0	15·364	87	88·0	53·224	303
·9	4·8860	89·0	15·451	87	89·0	53·526	302
9·0	4·9134	90·0	15·537	86	90·0	53·827	301
·1	4·9404	91·0	15·623	86	91·0	54·126	299
·2	4·9678	92·0	15·709	86	92·0	54·423	297
·3	4·9946	93·0	15·794	85	93·0	54·719	296
·4	5·0213	94·0	15·879	85	94·0	55·014	295
·5	5·0479	95·0	15·963	84	95·0	55·307	293
·6	5·0746	VIII. 96·0	16·047	84	96·0	55·597	290
·7	5·1011	97·0	16·130	83	97·0	55·886	289
·8	5·1275	98·0	16·212	82	98·0	56·172	286
·9	5·1538	99·0	16·293	81	99·0	56·455	283
10·0	5·1792	100·0	16·373	80	100·0	56·737	282

SECTION II.—WAVES OF THE SECOND ORDER.

Oscillating Waves.

Character	Gregarious.
Species	Stationary. Progressive.
Varieties	Free. Forced.
Instances.................	Stream ripple. Wind waves. Ocean swell.

The Standing Wave of Running Water.—Among oscillating waves of the second order, I know none more common or more curious than the standing wave of running water. I begin the account of my examination of waves of the second order, because it is that species which appears to me to be the most easy to be conceived, because it presents the closest analogy to the ordinary known phænomena of wave motion, and because, although most frequently exhibited to the eye of the common gazer, it has not, as far as I know, ever been made the subject of accurate observation.

If the surface of a running stream be examined as it runs with an equal velocity along a smooth and even channel, its surface will present no remarkable feature to the eye, although it is known by accurate observation that the surface of the water is higher above the level in the middle or deep part than at the sides of the channel. On the bottom of the channel let there be found a single large stone; this interruption, although considerably below the surface of the water, will give indication of its presence by a change of form visible on the surface of the water. An elevation of surface will be visible, not immediately above it, but in its vicinity. Simultaneous with the appearance of this protuberance, there will appear a series of others lower down the stream. These form a group of companion phænomena, are waves of the second order, oscillatory, and of the standing species, their place remaining fixed in the water, while the water particles themselves continue to flow down with the stream. For examples see Pl. LV.

This species of wave is especially deserving of the notice both of the mathematician and of the natural philosopher, for this cause especially, that the apparent motions of the water are in this case identical with the actual paths of individual particles; each particle on the surface actually describes the path apparent on the surface; the outline of the surface of the water is the true path of a particle during its progress down the stream. It does not exhibit like other waves the form merely, a form very different from the true motion of the water particles, nor does it exhibit the motion of a motion, nor do the particles themselves remain behind while they transmit forward the wave. The particles are themselves translated along the fluid in the paths which form the apparent outline of the fluid.

In this respect, therefore, this wave appears to me important as presenting a case of transition from ordinary fluid motion to wave motion.

I found by observation on a mountain stream that waves $3\frac{1}{2}$ feet long rise in water moving at the rate of $3\frac{1}{2}$ feet per second.

Also, that waves 2 feet long rose in water moving at $2\frac{1}{2}$ feet per second.

These numbers coincide with those given in Table XXI. from which the following approximate numbers are deduced. These numbers will enable an observer to judge of the velocity of a stream by inspection of the waves on the surface.

The length of wave being	1 inch,	the velocity of the stream per second is	$\frac{1}{2}$ foot.
„ „	*3 inches,	„ „ „	*1 foot.
„ „	1 foot,	„ „ „	$1\frac{3}{4}$ feet.
„ „	$1\frac{1}{4}$ feet,	„ „ „	2 feet.
„ „	2 feet,	„ „ „	$2\frac{1}{2}$ feet.
„ „	*$3\frac{1}{2}$ feet,	„ „ „	*$3\frac{1}{2}$ feet.
„ „	6 feet,	„ „ „	$4\frac{1}{2}$ feet.
„ „	7 feet,	„ „ „	5 feet.
„ „	10 feet,	„ „ „	6 feet.
„ „	*30 feet,	„ „ „	*10 feet.

This Table is given for convenience of reference to observers, and it is useful and easy to recollect the velocities corresponding to 3 inches, $3\frac{1}{2}$ feet, and 30 feet. By these means it will be easy for observers to verify or correct these numbers.

These waves are very peculiar in this respect, that they exhibit little or no tendency to lateral diffusion; the breadth of a wave does not apparently exceed the length of a wave, and is often much smaller. When a stream enters a large pool, its path across the pool is marked by these waves very distinctly, and the diminishing length of the waves accompanies the diminishing velocity of the stream, and at the same time indicates the extreme slowness with which diffusion takes place.

The motion of the particles of water, as observed by a body floating on the surface, is this, the motion is retarded at the top of each wave and accelerated in the bottom, thus oscillating about the mean motion of the stream. The motion, as far as it can be observed by bodies floating near the surface, is a simple combination of a circular with a rectilineal motion. The disturbing body, the stone at the bottom, gives to the particles which pass over it the motion of eddy as indicated, Plate LV. fig. 2, and this being continued downwards, and combined with the rectilineal motion of the particles, presents the cycloidal form of the wave.

If we conceive a uniform revolving motion in a vertical plane communicated to a particle of water, the centre of the circle of revolution being at the same time carried uniformly along the horizontal line, Plate LVI., then the path of the particle having these two motions is marked out by the cycloidal line 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 joining these points, and if every successive particle of the fluid have the same motions communicated to it, the simultaneous places of successive particles will give the line 1, 2, 3, 4, 5, 6, 7, 8, &c. as the form of the surface of the fluid. It is to be observed that at A and C the direction of the motion of revolution is opposite to the motion of transference, and ∴ the absolute velocity of the particle is diminished by the oscillating motion, while at B and D it is increased by an equal amount, and in the intermediate positions 3 and 9 it is neither increased nor diminished. It is also to be observed, that when the motion of the water in the direction of transference is slowest (*i. e.* when the motion of oscillation is opposite to the motion of transference), the transverse section of moving fluid is greatest, and when the motion of transference and of oscillation coincide, and the motion is quickest in the direction of transference, the transverse section of the fluid is greatest. Thus we see how during a change of form the dynamical equilibrium of the fluid may be unchanged.

The fluid may thus be conceived as moving with varying velocity along a channel of variable section, its upper surface being conformable to the outline of the wave. Hence we might infer that a rigid channel of varying area, of the form of this standing wave, would not interfere with the free motion of the fluid.

And hence it may follow, that when the area of a pipe conveying fluid is to undergo a change, the best form of pipe or channel is indicated by the form of this wave. Thus the velocity has undergone a change between 0 and 4 which the form of a close pipe might render permanent.

In the examples already given, a solid impediment has generated the waves on the surface of the fluid. At the confluence of streams I have observed the same waves generated by the oblique action of one current on another meeting it in a different direction.

The height and hollow of the fluid and the change of velocity are to be regarded as reciprocally the cause and effect each of the other. The obstacle first retards the velocity of the fluid, so as to accumulate it above the obstacle, the water rises to a height due to this diminished velocity, and as all the particles of the stream pass through this area of the stream with a diminished velocity, the area of transverse section must be increased at this point; thus the elevation of surface, enlargement of section, diminution of velocity above the obstacle are its necessary consequences of that obstacle. Again, below the obstacle the accumulation above generates an additional velocity due to that height in addition to the mean motion of the stream; the same volume of water which passed through the large area, with its increased section and diminished velocity, being now a higher velocity, is transferred through the smaller area which allows its transmission. Thus the constant volume passing down the stream varies its velocity with the conservation of its forces by means of a varying area of transference; and thus we are enabled to conceive how the observed form of the surface becomes at once possible and necessary to the transmission of the fluid under the action of the disturbing force.

I am not aware that this species of standing wave in moving water has ever before been made the subject of philosophical examination. But I conceive that its study is highly important, especially in a theoretical view, as the means of conveying sound elementary conceptions of wave motion, as exhibiting the transition from the phænomena of water currents to those of water waves, as the intermediate link between motions of the first degree and motions of the second degree, and as affording a basis from which we may commence, with some prospect of success, the application of the known principles and laws of motion to the investigation of the difficult theory of waves.

Moving Waves of the Second Order—Sea Waves.—It is not difficult to pass from the conception of standing waves in running water to the conception of running waves in standing water. Let us first conceive the waves in Plate LV. to be formed in water running in the direction there indicated from right to left, with a given mean motion, and a given motion of uniform circular oscillation: and next let us conceive the whole water channel and waves to be transferred uniformly in the opposite direction with a velocity equal to the mean velocity of transference; then the absolute motion of transference of the water will become nothing: the waves formerly standing are now moved in the opposite direction with a velocity equal to the former mean velocity of the running stream, and the motion of oscillation remains. Thus, the running water becoming still, the waves become moving waves, and if we reverse the hypothesis once more, and conceive the waves which move with a given velocity to exist in water which has a motion of transference with equal velocity in the opposite direction, it is manifest that these waves running up the stream as fast as the waters run down, the wave-crests remain fixed in place. Thus then the same oscillating phænomenon which in standing water gives moving waves, will give in moving water standing waves; taking for granted always that the motions of oscillation are such as to be possible, consistent with the nature of the fluid, and independent of the common mean motion of the fluid; a condition equally essential to the possibility of the wave motion and of our conceptions of it.

I have been able accurately to observe the phænomena of wave motion in still water, the waves being of the second order and gregarious, under the following circumstances:—

1. I have drawn a body through the water with a uniform motion, and have observed the group of waves which follow in its wake.

2. I have propagated the negative wave of the first order, and observed the group of waves which follow in its wake.

I have not observed in the results of these two methods any distinction of form, velocity, or other character.

The form under which these waves appear has already been exhibited in Plate LII. figs. 9 and 10, and equally in Plate LV. figs. 1, 2, 3, and in Plate LVI. fig. 1.

I have made a series of observations by dragging a body through the water, the results of which are given in the following Table. I first made preparatory observations to find whether the form of body or depth of channel made any change on the phænomenon. I found that larger bodies and higher velocities made higher waves, but that the length and velocity of the wave were unchanged by either the form of body, or the depth of the channel, or the height of the wave. I observed that when the waves became high and broke, the elevation above the mean level was 6 inches, and the depression below it 2 inches, making a height total of 8 inches; this was at a velocity of 6·25 feet per second. Immediately behind the body dragged through the water, the mean level appears to be considerably lowered.

I examined the motion of oscillation of these waves by means of small floating spherules. Waves of the second order having a total height of half an inch, in water 4 inches deep made by a negative wave, were accompanied by motion in a circle of half an inch diameter at the surface, and the particles below described also circles which rapidly decreased in diameter and at 3 inches deep ceased to be sensible; the waves were about one foot long.

TABLE XIX.

Observations on the Length and Velocity of Waves of the Second Order.

Column A the order and number of the experiments.

Column B the number of seconds in which the waves were transmitted along 100 feet.

Column C the aggregate length in feet of the number of waves in Column D.

Column D the number of waves extending to the length in Column C.

Column E the length in feet of one wave from crest to crest.

Column F the velocity in feet per second given by experiment.

These results are the means of many experiments, differing from each other not more than the examples preceding them, which have been given in detail as a fair specimen.

A.	B.	C.	D.	E.	F.	A.
I.	33·2	26·5	10	2·65	3·01	I.
II.	33·2	26·5	10	2·65	3·01	II.
III.	31·6	25·	8½	2·94	3·16	III.
IV.	31·8	25·	8½	2·94	3·14	IV.
V.	31·8	25·	8½	2·94	3·14	V.
VI.	30·4	25·	8	3·125	3·29	VI.
VII.	29·6	25·	7⅔	3·26	3·37	VII.
VIII.	29·6	25·	7⅔	3·26	3·37	VIII.
IX.	28·0	25·	7	3·57	3·57	IX.
X.	28·4	25·	7	3·57	3·51	X.
XI.	28·0	25·	7	3·57	3·57	XI.
XII.	28·0	25·	7	3·57	3·57	XII.
XIII.	28·0	25·	7	3·57	3·57	XIII.
XIV.	28·0	25·	7	3·57	3·57	XIV.
†XV.–XVII.	26·8	25·	6½	3·84	3·72	XV.–XVII.
†XVIII.–XXII.	26·0	25·	6	4·18	3·84	XVIII.–XXII.
†XXIII.–XXVI.	24·0	25·	5	5·00	4·16	XXIII.–XXVI.
†XXVII.–XXXIV.	21·6	25·	4	6·25	4·62	XXVII.–XXXIV.

As these waves appear in groups, their velocity and lengths are easily observed and measured. I have reckoned as many as a dozen such waves in a group all about the same magnitude, so that the aggregate length of the first six was sensibly equal to the length of the second group of six. The method of observation was this: a given distance was marked off along one side of the channel; an observer marked the instant at which the first of a group of secondary waves arrived at a given point, while another observer at the further end of the given distance counted the number of waves as they passed, and marked the point at which the last had arrived when the signal was given that the first wave had reached the other station; thus it was observed that in a group of waves moving over 100 feet in 28 seconds, there were seven comprehended in a distance of 25 feet, whence

$$\frac{28}{100}=3{\cdot}57 \text{ feet per second for the velocity of the wave, and}$$

$$\frac{25}{7}=3{\cdot}57 \text{ feet as the length of the wave.}$$

Also, since the wave passes along 3·57 feet its own length in one second, its length divided by the velocity gives 1 second as the period of one complete oscillation.

The *velocity* of the wave of the second order, the *length* from the crest of one wave to the crest of the next, or from hollow to hollow, and the time of passing from one crest to another, called the *period* of the wave; these are the principal elements for observation.

These elements are calculated for the convenience of observers in the Table XXI. It will also be observed that the circles which represent the oscillatory motion of the water particles (Plate LVI.), showing the Wave Motion of the Second Order, diminish very rapidly with the increasing depth of the particles below the surface of the water at the lowest part of the wave. By my observations I found that in high waves at a depth $= \frac{1}{3}$rd of a wave length, the range of oscillation of the particles is only about $\frac{1}{30}$th of that of particles on the surface*.

* I have here to express the favourable opinion which I have formed of a wave theory given to the world by M. Franz Gerstner, so early as 1804*, and reprinted in the work of the MM. Weber, to whom I am indebted for my acquaintance with this theory. Gerstner's theory is characterized by simplicity of hypothesis, precision of application, its conformity with the phænomena, and the elegance of its results. It is not without faults, yet I cannot agree with the Messrs. Weber, nor with MM. Professors Mollweide and Mobius, in the precise opinion at which they arrive, although I confess I could wish that he had assumed as an hypothesis the doctrine which in (14.) he deduces as a conclusion from hypotheses less firmly established than this conclusion, unless indeed we should esteem it an argument in favour of his hypothesis, that it conducts him directly to a conclusion of well-known truth. Neither do I find that his hypotheses are so much at variance with the actual conditions of the waves I have observed, as they appear to be in MM. Weber's view of their own experiments. The calculations of M. Gerstner are applied primarily to a kind of standing oscillation. But it does not appear to me that his calculations ought to be applied in any way to the standing oscillations which M. Weber reckons to be their closest representation. In M. Gerstner's first part of the work the wave form is standing, wave oscillation is circular, the fluid is in motion, and the particle paths are identical with the lines which indicate the form of the wave. I conceive, therefore, that the wave which he has examined, and the conditions of its genesis, find a perfect representative in my standing waves of the second order, in running water, which I have represented in Plates LV. and LVI. From this hypothesis it is not difficult to arrive at the moving wave of standing water, for if we conceive the whole channel moved horizontally along in an opposite direction with a velocity equal to the horizontal velocity of transference, the particles will then be relatively at rest, the cycloidal waves become moving forms, the particle paths stationary circles, and the motion of transmission of the wave equal and opposite to the former mean horizontal

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* Theorie der Wellen. Prague, 1804.

One observation which I have made is curious. It is, that in the case of oscillating waves of the second order, I have found that the motion of propagation of the whole group is different from the apparent motion of wave transmission along the surface; that in the group whose velocity of oscillation is as observed 3·57 feet per second, each wave having a seeming velocity of 3·57, the whole group moves forward in the direction of transmission with a much slower velocity. The consequence of this is a difficulty in observing these waves (especially such as are raised by the wind at sea), namely, that as the eye follows the crest of the wave, this crest appears to run out of sight, and is lost in the small waves in which the group terminates. The termination of these groups in a series of waves becoming gradually smaller and smaller, yet all continuous with the large wave, is curious and leads to a curious conclusion. It is plain that if these large waves are moving with the same velocity as the small ones, this result would be inconsistent with the other experiments. But if we conceive each to be transmitted with the velocity due to its breadth, we shall have the velocity of oscillation varying from point to point in the same group of waves, but it will be impossible always to measure this velocity directly as it may be continually changing. There is to be observed, therefore, this distinction in a group of waves of the second order, between the velocity of individual wave transmission and the velocity of aggregate wave propagation.

I have not found it possible to measure this velocity of aggregate propagation of a group of waves, from want of a point to observe. If I fix my eye upon a single wave, I follow it along the group, and it gradually diminishes and then disappears; I take another and follow it, and it also disappears. My eye, in following a wave crest, follows the visible velocity of transmission merely. After one or two such observations, I find that the whole group of

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motion of transference of the particles. In short, they become moving waves of the third order, the common waves of the sea.

From M. Gerstner's investigations we obtain the following results, for oscillating waves which correspond to our second order:—

1. Waves of the same amplitude are described in equal times independently of their height. (This corresponds with the results of our experiments.)

2. Waves are transmitted with velocities which vary as the square roots of their amplitudes.

3. The waves on the surface are of the cycloidal form, always elongated, never compressed; the common cycloid being the limit between the possible and impossible, the continuous and the broken wave.

4. The particle paths in the standing waves of running water are cycloids, which on the surface are identical with the wave form, and below the surface have the same character with the wave lines of the surface, the height of the waves only diminishing with the increase of depth.

5. The particle paths of moving waves in standing water are circles corresponding to the circles of height of the cycloidal paths; the diameters of these circles of vertical oscillation diminish in depth as follows. Let 0, u, $2u$, $3u$, &c. be depths increasing in arithmetical progression, then b, $b\varepsilon^{-\frac{u}{a}}$, $b\varepsilon^{-\frac{2u}{a}}$, $b\varepsilon^{-\frac{3u}{a}}$, which decrease in geometrical proportion, are the ratio of the diminishing diameters of vertical oscillation. Thus, if 0, $\frac{1}{2}a$, $\frac{2}{2}a$, $\frac{3}{2}a$, &c. be depths, a, $0·6065\,a$, $0·3679\,a$, $0·2231\,a$, $0·1353\,a$, are the ranges.

6. The forms of these paths and the circles of oscillation are shown in Plate X. fig. 1, which has been drawn with geometrical accuracy from the data of M. Gerstner's theory, and it is at the same time the most accurate representative I am able to give of my observations on the wave of the second order.

7. The period of wave oscillation is $t=\pi\sqrt{\frac{2a}{g}}$.

8. The velocity of wave propagation is $v=\sqrt{2ag}$, a being the radius of the wave cycloid generating circle.

9. It follows that the length of a pendulum isochronous with the wave is less than the wave length in the ratio of the diameter of a circle to its semi-circumference. Newton made these equal. These last three results are inconsistent with my observations on transmission.

oscillations has been transferred along in the direction of transmission with a velocity comparatively slower; but I have not been able to measure this velocity of propagation of the wave motion from one place to another.

We have already seen that the velocity assigned by Mr. Kelland and Mr. Airy falls much short of that of the wave of the first order, to which they have thought their results were to be applied. Their results are much nearer to that of the secondary wave, so that it may be questioned whether they should not have applied their results to that rather than the other. Thus by comparing Table XXI. with Table XVIII., it will be found that while the velocity of a wave of the first order, about 6 feet long, is from 5·5 to 8 feet per second, according to the height, that of a wave of the second order is only 4·62 feet, which is much nearer to their results. There remains however this difficulty, that high and low waves of the second order of equal length have equal velocities.

On Observations of the Waves of the Sea.—The chief difficulty in obtaining accurate measures of sea waves consists in this fact, that the surface is seldom covered with a uniform series of equidistant equal waves, but with several simultaneous groups of different magnitude or in different directions. If there exist more groups than one, the resulting apparent motion of the surface will be extremely different from the motion of either, and may be apparently in an opposite direction from that of the actual motion of the individual series themselves.

Besides the coexistence of different series of waves, we have the difficulty arising from the fact already mentioned, that a difference exists between the velocity of transmission and the velocity of propagation. From this it results, that after the eye has followed the apparent ridge of a wave, moving with a given velocity of transmission, it will outrun the velocity of propagation, and the wave will appear to cease. This I have continually observed at sea. The eye follows a large wave and suddenly it ceases to pass on, but on looking back we find it making once more an appearance on the same ground along which we formerly traced its ridge; this arises from the cause just mentioned.

But there are still many occasions on which tolerable observations may be made, and the best will be such as are least complicated by separate systems. The best observations of this kind I have been able to obtain were made for the Committee of the British Association, by the Queen's Harbour-master at Plymouth, William Walker, Esq., who has paid much attention to this subject. He observed the waves as they traversed a space of about half a mile, between two buoys, noting the time of passing, and also the number of waves in the distance between the buoys, whose distance was accurately known. He remarks that in counting the number of waves, great difficulty was found in following a single wave along this space. In fact, as we have already shown, a wave will be often found to fall behind its expected place.

The resulting velocities got from Mr. Walker's experiments are very various. But on taking out of the others all those which are mentioned by Mr. Walker as having causes of uncertainty, I found those which remained very close to those given in Table XXI.

The following is the Table of observations on sea waves.

Distance traversed about half a mile; depth 40 to 50 feet.

TABLE XX.

Observations on the Length and Velocity of Waves of the Second Order.—In the Sea.

	Wave length. feet.	Vel. per sec. feet.	Vel. per hour. miles.	Height of wave in feet above mean level.	Remarks at the time of Observations.
I.	110·5	20·2	11·9	2¾	A fresh breeze blowing.
II.	175·0	34·3	20·3	2½	Waves not easily traced.
III.	302·	37·0	21·9	4	High seas overtake smaller ones.
IV.	345·	37·0	21·9	4½	These waves came down channel.
V.	306·	37·0	21·9	4½	Long low swell.
VI.	408·	41·2	24·2	4½	Small waves merged in large ones.
VII.	442·	41·8	24·7	27	Height of wave correctly measured, they break in 5 and 6 fathoms water.
VIII.	450·	44·7	26·5	?	Strong S.W. wind.
IX.	460·	46·0	27·2	?	Waves running high and breaking.
X.	345·	46·0	27·2	5	Long low swell.
XI.	394·	38·3	22·7	5	Waves generated by wind of yesterday.
XII.	345·	41·5	24·5	4	Waves crowd near the beach.
XIII.	306·	36·8	21·6	irregular.	Shifting wind.
XIV.	460·	42·5	25·2	regular.	Easterly winds.

Of these there are five which coincide with my observations and with my tables, Nos. XIX. and XXI.; and it is curious that these five are those which are made in the most unexceptionable circumstances. No. II. has the remark that the waves are not easily traced. No. III. has a mixture of waves, which always causes great confusion and difficulty of observation. No. V. and No. X. are long and low, and therefore not easily traced, and so on; but Nos. I., IV., VII., XI., XIV., are unexceptionable, and are compared with my formula in the following Table :—

	Length of wave observed. feet.	Velocity of wave observed. feet per sec.	Velocity of wave calculated.
I.	110·5	20·2	19·5
IV.	345·	37·0	35·
VII.	442·	41·8	40·
XII.	394·	38·3	37·
XIV.	460·	42·	40·*

We may therefore continue to use Table XXI. for the velocity of sea waves, unless we obtain further and decisive experiments to the contrary. It does not appear that sea waves present any characteristic to distinguish them from other oscillating waves of the second order which I have experimentally examined.

It also follows that these waves coincide with my observations, that the depth of water is the limit of the height of waves; see No. VII., where waves 27 feet high, break in water of 5 to 6 fathoms.

How it happens that individual large waves should ever arise in the surface of a large sea, uniformly exposed to the action of the wind, is not very obvious. Thus much is plain—that if a wave, greater than those around it, be generated by a local inequality of the wind, or by one of the moving whirlpools which we know to be so common, *that wave* will be increased continually by the presence of other waves coexisting with it, for when these other waves are crossing the top of this larger wave, they are suddenly exposed to increased force by the obstruction they present to the wind, and being cusped in form by the coincidence of the crests, they are in a position of delicate equilibrium easily deranged; and the derangement producing a breaking of the wave, the disintegrated fragments of the smaller wave detached from it, leave it smaller, and increase by an equal quantity the magnitude of the larger.

This exaggeration of an individual wave or group is increased by the phænomenon already noticed, that the velocity of wave *transmission* may be very different from the velocity of wave *propagation*. A large wave of the sea remaining in a state of much slower motion than the motion of wave transmission, being traversed by another series of different velocity, exposes them successively on its summit to the increased action of the wind to disintegration, thus making them tributary to its own further accumulation; such phænomena I have often noticed at sea; the wave appears to over-run itself; and the wave behind *seems* to take its place and acquire the magnitude and form it has appeared to lose; but it is the same wave which remains behind it, and its motion is merely a deception, or rather it is as explained in a preceding paragraph.

The final destruction of the waves of the sea, as they expend their strength and conclude their existence on the rocks and sands of the shore, is a subject of interesting study and observation. The sea-shore after a storm is a scene of great grandeur; it presents an instance of the expenditure of gigantic forces, which impress the mind with the presence of elemental power as sublime as the water-fall or the thunder. It is peculiarly instructive to watch these waves as they near the shore: long before they reach the shore they may be said to feel the bottom as the water becomes gradually more shallow, for they become sensibly increased in height; this increase goes on with the diminution of depth and a diminution of length likewise as the wave becomes sensible; finally, the wave passes through the successive phases of cycloidal form, as in Plate LVI., and becoming higher and more pointed, reaching the limit of the cycloid, assumes a form of unstable equilibrium, totters, becomes crested with foam, breaks with great violence, and continuing to break, is gradually lessened in bulk until it ends in a fringed margin on the sea-shore.

But there are a variety of questions to be determined concerning this shore wave or breaking surf. Why and how does it break? What happens after it begins to break? What are the relative levels of the waves and of the water? What is the mean level of the sea, and what sort of waves are breakers?

It is not at first obvious what form the mean level of the sea will assume on a sloping beach sea-ward on which heavy breakers are rolling. It is plainly not level; the action of the wind is known to heap the water up on it. The impetus of the waves also must raise it to some height due to their velocity and force. Hence the mean surface of the sea will form a slope upwards towards the sea-shore; and this slope will form a continual and uniform current of water outwards towards the sea, except when it is directly opposed by the action of the wave in the opposite direction.

There is a phænomenon of some importance in breaking waves, to which I have directed attention; it is this, that the wave of the second order disappears, and that a wave of the first order takes its place. It is to be observed as follows:—In waves breaking on a shore, I have observed a phænomenon which is curious and not without importance. The wave of the second order may disappear, and a wave of the first order take its place. The conditions in which I have noticed this phænomenon are as follows. One of the common sea waves, being of the second order, approaches the shore, consisting as usual of a negative or hollow part, and of a positive part elevated above the level; and as formerly noticed, this positive portion gradually increases in height, and at length the wave breaks, and the positive part of the wave falls forward into the negative part, filling up the hollow. Now we readily enough conceive that if the positive and the negative part of a wave were precisely equal in height, volume, and velocity, they would, by uniting, exactly neutralize each other's motion, and the volume of the one filling the hollow of the other, give rise to smooth water; but in approaching the shore the positive part increases in height, and the result of this is, to leave the positive portion of the wave much in excess above the negative. After a wave has first been made to break on the shore, it does not cease to travel, but if the slope be gentle, the beach shallow and very extended (as it sometimes is for a mile inwards from the breaking-point, if the waves be large), the whole inner portion of the beach is covered with positive waves of the first order, from among which all waves of the second order have disappeared. This accounts for the phænomenon of breakers transporting shingle and wreck, and other substances shorewards after a certain point; at a great distance from shore, or where the shores are deep and abrupt, the wave is of the second order, and a body floating near the surface is alternately carried forward and backward by the waves, neither is the water affected to a great depth; whereas nearer the shore, the whole action of the wave is inwards, and the force extends to the bottom of the water and stirs the shingle shorewards; hence the abruptness also of the shingle and sand near the margin of the shore where the breakers generally run.

I have observed this most strikingly exemplified in Dublin Bay after a storm: there is a locality peculiarly favourable to the study of breaking waves above Kingston, where over an extent of several miles there is a broad, flat, sandy beach, varying in level very slightly and slowly. Waves coming in from the deep sea are first broken when they approach the shallow beach in the usual way; they give off residuary waves, which are positive; these are wide asunder from each other, are wholly positive, and the space between them, several times greater than the amplitude of the wave, are perfectly flat, and in this condition they extend over wide areas and travel to great distances. These residuary positive waves evidently prove the existence, and represent the amount of the excess of the positive above the negative forces in the wind wave of the second order. See Plate XLIX. fig. 7.

TABLE XXI.

Length, Period and Velocity of Transmission of Waves of the Second Order.

A the length of the waves (observed) in feet.
B the period of the waves in seconds.
C the velocity of the waves in feet per second (by observation).
D the velocity of the waves in feet per second, calculated by formula.

A.	B.	C.	D.	A.	A.	B.	C.	D.	A.
0·01	·053		·1889	0·01	8	1·496		5·344	8
0·05	·118		·4224	0·05	9	1·587		5·667	9
0·1	·167		·5975	0·1	10	1·670		5·975	10
0·25		1·00			20	2·366		8·45	20
0·3	·290		1·034	0·3	30	2·90		10·34	30
0·5	·374		1·336	0·5	40	3·34		11·95	40
0·7	·443		1·580	0·7	50	3·74		13·36	50
1·0	·529		1·889	1·0	100	5·29		18·89	100
1·2	·579		2·070	1·2	110		20·	19·5	
1·5	·648		2·314	1·5	200	7·48		26·72	200
1·7	·690		2·463	1·7	300	9·16		32·73	300
2·0	·748		2·672	2·0	345		37·	35·	
2·2	.781		2·802	2·2	394		38·	37·	
2·4	·820		2·927	2·4	400	10·58		37·78	400
2·65	·862	3·01	3·075	2·65	442		42·	40·	
2·94	·907	3·15	3·240	2·94	460		42·	40·	
3·00	·916		3·273	3·00	500	11·83		42·25	500
3·12	·934	3·29	3·338	3·12	1,000	16·70		59·75	1,000
3·26	·955	3·37	3·411	3·26	2,000	23·66		84·5	2,000
3·57	1·000	3·57	3·57	3·57	3,000	29·0		103·4	3,000
3·84	1·038	3·72	3·702	3·84	4,000	33·4		119·5	4,000
4·00	1·058		3·778	4·00	5,000	37·4		133·6	5,000
4·18	1·095	3·84	3·909	4·18	10,000	52·9		188·9	10,000
4·50	1·122		4·008	4·50	20,000	74·8		267·2	20,000
4·70	1·147		4·096	4·70	30,000	91·6		327·3	30,000
5·00	1·183	4·16	4·225	5·00	40,000	105·8		377·8	40,000
6·00	1·296		4·628	6·00	50,000	118·3		422·5	50,000
6·25	1·323	4·62	4·724	6·25	100,000	167·0		597·5	100,000
6·5	1·349		4·817	6·5	500,000	374·0		1336·0	500,000
7	1·400		4·999	7	1,000,000	529·0		1889·0	1,000,000

SECTION III.—WAVES OF THE THIRD ORDER.

Capillary Waves.

Character............	Gregarious.
Varieties............	Forced. Free.
Instances............	Dentate waves. Zephyral waves.

Capillary Waves.—If the point of a slender rod or wire, being wet, be inserted in a reservoir of water perfectly still, to a minute depth, say one-tenth part of an inch below the surface of repose, it is known that the surface of the water will visibly rise in the vicinity of this wire, being highest in the immediate vicinity of the wire, and gradually diminishing until it cease to be sensible. I have examined this elevation by reflected rays from the surface, and I find that this elevated mass does not sensibly rise from the surface at more than an inch distance from the centre of the rod, the rod itself being one-sixteenth of an inch in diameter.

This statical phænomenon belongs to a well-known class of phænomena, which have been experimentally examined by many philosophers, and successfully explained by Dr. Thomas Young and Laplace, and recently investigated very fully and completely by M. Poisson, in his profound work entitled, 'Nouvelle Théorie de l'Action Capillaire,' Paris, 1831. An admirable Report on the present state of our knowledge of the phænomena of capillary attraction will be found in the Transactions of the British Association, vol. ii. All that it is necessary for my present purpose to advert to on this subject is, that the phænomena of elevation of fluids by capillary attraction, are chiefly due to the condition of tension of the superficial particles of the water under the influence of a force acting on these superficial particles at insensible distances only, or by physical contact or adhesion. These superficial particles form a chain, or catenary, or lintearian curve, one end supported by the immediate adhesion of one extremity to the solid body at a given height above the water, the other end lying on the surface of the water, the underlying particles being suspended immediately by their mutual adhesion to this superficial film. M. Poisson especially has shown that "capillary phænomena are due to molecular action, modified by a particular state of compression of the fluid at its superficies." I have been thus particular for the purpose not only of explaining my meaning in a future article, but also to justify a term which I am desirous of introducing here as an expression not only convenient, but also philosophically sound. I have called the phænomena noticed in this section *Capillary Waves*, because they appear to me to present themselves exclusively in the thin superficial film which forms the bounding surface of the free liquid, and which is already recognised in the known hydrostatical phænomena of capillary attraction, and which if I may be allowed, I will call the *capillary film.*

By capillary waves I therefore designate a class of hydrodynamical phænomena, which exhibit themselves when particles of water are put in motion under the action of such forces as when at rest produce the usual hydrostatical capillary phænomena. Let the slender rod already alluded to, as supporting a capillary column, bounded by a concave surface of revolution, be moved horizontally along the surface of the fluid with a velocity of one foot per second, and we shall have exhibited to us all the beautiful phænomena represented in Plate LVII. In order to produce these phænomena, it is only necessary that the slender rod touch the surface without descending to any sensible depth; and the depth to which it descends in no sensible manner affects the phænomenon. I have called these phænomena capillary waves.

Free Capillary Waves.—If the point of a rod sustaining a capillary column be suddenly raised, so as to allow the capillary film to remain without support, it descends and propagates through the capillary film an undulation which diffuses itself in every direction circular-wise, in a small group of about half a dozen visible waves which soon become insensible. Or if a very slender silk fibre, stretched horizontally along the surface of the water, be first wetted, and made to sustain a long strip of the capillary film, and then suddenly withdrawn, leaving a ridge of unsupported fluid, waves parallel to this are generated, which remain longer visible, are short and narrow at first, and becoming longer and flatter, at first about a quarter of an inch in amplitude from ridge to ridge, and about half a dozen in number, they become an inch in amplitude about the time when they are last visible; their *longevity* does not exceed *twelve or fifteen seconds,* and their *visible range eight or ten feet.*

These latter are what I designate the *free* capillary waves; the former class, shown in Plate LVII., existing under the continued influence of the disturbing force, may be called the *forced* species of this order of wave. As forced waves, and while under the influence of the exciting body, they may apparently attain great velocity; but if the disturbing body be suddenly removed, they immediately expand backwards from the place where they were crowded by the solid point, and becoming all of nearly equal breadth, move forward together as free waves for twelve or fifteen seconds, at a rate of 8½ inches per second.

Forced Capillary Waves.—I have already stated that if a slender rod or wire, one-sixteenth of an inch in diameter, be inserted, after having been wetted, into water in repose, there will be raised all round this rod a column of fluid by the action of the capillary forces, as indicated at figure 2, Plate LVI. I have stated that this surface may be observed by reflexion to extend on every side about an inch, forming a circular elevation, bounded by a surface of revolution round the axis of the rod as a centre; the line which divides the elevated from the level surface being a circle of two inches in diameter. When this rod is moved horizontally along the surface of the fluid, the form of the elevated mass changes; before the disturbing point the extent of elevation diminishes, and the outline of the capillary volume of fluid sustained by the cylinder ceases to be a figure of revolution, becoming distorted as at fig. 3. At a velocity of about eight inches per second, the capillary volume has taken the bifurcate form, fig. 6, and a small wave, *b b*, about an inch broad, is visible before the disturbing point, and a ridge, *a a*, begins to manifest itself, diverging from the disturbing body; at about ten inches per second there become visible distinctly three waves, the disturbing body being in the middle of the first *a*, and the sum of the length of waves *b* and *c*, being about an inch. At higher velocities than this, the waves increase rapidly in number, diminish in amplitude, and extend out in length, spreading into the form indicated in Plate LVII., which is formed at a velocity of 60 feet per minute, or of 12 inches per second.

As the velocity increases, the following changes are to be observed:—1. The waves diminish in amplitude from ridge to ridge; that is to say, denominating the wave in which is the disturbing body ridge *a*, and the others in succession before the point *b c d*, &c. the first space of an inch forward, in the direction of motion contains at a velocity of 12 inches per second, or 60 feet per minute, besides *a*, 3 ridges *b c d*; at 65 feet per second, 4 ridges *b c d e*; at 72 feet per second there are in the first inch formed five ridges *b c d e f*, and so on. This crowding of the ridges with the velocity is given in the following Table:—

Table XXII.

Observations on the Velocity, Distance, and Divergence of Waves of the Third Order.

Column A contains the time in which the disturbing body, a wire of one-sixteenth of an inch in diameter, was drawn with a uniform motion along distances of 12 feet each ; each experiment being frequently repeated.

B and C are the corresponding velocities of the disturbing body.

D, E, F are the number of complete waves, reckoning from hollow to hollow, contained in each successive inch from the centre of the disturbing wire, formed in the direction of the motion of the wire.

G. The numbers in this column are measures of the divergence of the first wave from the path of the exciting wire, measured at 25 inches behind that wire, and of course these numbers are tangents to the radius 25 for the angle of divergence.

H contains the angles deduced from the numbers in G.

Observations on the Capillary Waves.

See Plate LVII.

	A.	B.	C.	D.	E.	F.	G.	H.
	Time of describing 12 feet.	Velocity in feet per sec.	Velocity in feet per min.	No. of waves observed before the disturbing body,			Tang. of angle to radius 25.	Angle of crest of first wave *aa*, with direction of disturbing bodies.
				in first inch.	in second inch.	in third inch.		
	s.							°
I.	12	1	60	3	4	5 ?	25	45
II.	11	$1\frac{1}{11}$	65	4	5	6 ?	21	40
III.	10	$1\frac{2}{10}$	72	5	6	7 ?	17	34
IV.	9	$1\frac{3}{9}$	80	6	7		14	29
V.	8	$1\frac{4}{8}$	90	7	8		11	24
VI.	7	$1\frac{5}{7}$	103	8			9	20
VII.	6	2	120	9			8	18
VIII.	5	$2\frac{1}{5}$	132				7	
IX.	4	3	180				6	

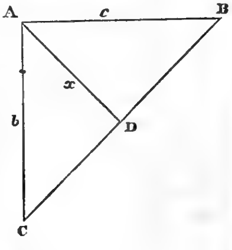
The crowding of the ridges is not the only phænomenon that accompanies the increase of velocity of the moving point ; the first wave, that whose ridge is in the focus, scarcely differs from a straight line, and the angle which it makes with the path of the disturbing point, diminishes with the increase of velocity ; the divergence of the first wave from the path of the exciting body is given in another column by an observation of the distance of the wave from that path at a given distance behind the body. These numbers show that the velocity of the wave, taken at right angles to the ridge, is nearly that of the free wave. This angle therefore becomes an index of the relation of the velocity of disturbance to the velocity of wave propagation.

The form of the wave ridges appears to be nearly that of a group of confocal hyperbolas, the exciting body being in the focus.

I have found the numbers given in columns C, D and E, to be determined by the velocity of the disturbing body, and quite independent of its size and form. But while I have found the number of ridges in an inch at a given velocity to be thus invariable, I have not found the number of inches over which these vibrations range to be equally invariable. At a velocity of 100 feet per minute, they may sometimes be observed advancing only over the first two inches before the point; then suddenly the vibrations will spread out, not increasing in magnitude but in number to thirty or forty, extending along many inches in advance of the disturbing point, and covering ten or twelve square feet with an extension of the representation in Plate LVII. Then suddenly without apparent cause, they will subside and become visible only as a thin narrow belt, comprising the two or three waves nearest the disturbing body, and as suddenly will again spread out over the surface of the water. The play of this beautiful symmetrical system of confocal hyperbolas is a phænomenon not inferior in beauty to some of the exquisite figures exhibited by polarising crystals. I have found that the purity of the water had much to do with the extent and range of this phænomenon; that any small particles loading at a few points the capillary film was sufficient to derange the propagation of these waves, and prevent their distribution over a wide range; but I have not found that the agitation of the water at all affected the formation of these waves.

It is perhaps of importance to state that when these forced waves were being generated, I have suddenly stopped or withdrawn the disturbing point, that the first wave immediately sprang back from the others, showing that it had been in a state of compression—that the ridges became parallel, and moving on at the rate of $8\frac{1}{2}$ inches per second, disappeared in about 12 seconds.

The manner in which the divergence of the ridge passes through the point of disturbance is shown in the annexed diagram. A B is the path of disturbance, the disturbing point being in B; a rod B A is 25 inches long; B C is the diverging wave ridge; a graduated rod A C projects from A B at the point A, 25 inches behind B, on which are observed the distance of the wave from A along A C, registered in Col. *b*, Table XXIII.



If a body move with a given velocity along a known line A B, the side A C being measured at right angles to the line of direction A B, and cutting, in C, the line B C which represents the ridge of the wave proceeding from the moving body B; it is required to find the velocity of the wave in the line A D perpendicular to its ridge.

As the triangle A B C is right-angled, $\sin B = \frac{\sin A \times b}{\sqrt{b^2 + c^2}}$;

and since the triangle A B D is right-angled, $x = \frac{\sin B \times c}{\sin D}$;

hence, the time being the same as that in which A B is described, the velocity is at once obtained.

Table I. contains some observations which were made with a view to the investigation of the ratio subsisting between these velocities. The sides and angles are indicated by the same letters which are used in the diagram.

c, its velocity, and *b* being given; *x*, its velocity, and B were calculated by means of the preceding formulæ.

TABLE XXIII.

Comparison of Experiments on the Divergence due to given Velocities of Genesis.

Column c is the constant measure in inches taken along the path of genesis A B in the figure; the adjacent column is the velocity of genesis along A B in inches per second.

Column b is the length A C, measured by observation in a direction at right angles to A B.

Column x is the length of x deduced from the measure b, and the adjacent column shows the corresponding deduced velocity of the wave at right angles to its ridge.

Column B shows the angles of divergence given by these observations.

Column b' and B′ are numbers corresponding to b and B obtained from the supposition that the velocity of the wave in a direction at right angles to its own ridge is constant and precisely equal to the velocity of the free wave, viz. $8\frac{1}{2}$ inches per second. The deviations of b' and B′ from b and B were chiefly due to disturbance of the fluid produced by the apparatus employed in genesis.

c.	Velocity in inches per sec.	b.	x.	Velocity in inches per sec.	B.			b'.	B′.		
					°	′	″		°	′	″
25	12	25	17·67	8·49	45	0	0	25·0	45	0	0
25	13	21	16·07	8·37	40	0	1	21·60	40	49	48
25	14·4	17	14·05	8·10	34	13	7	18·27	36	10	26
25	16.0	14	12·16	7·79	29	7	46	15·67	32	5	23
25	18·0	11	10·05	7·28	23	42	55	13·38	28	9	32
25	20·6	9	8·44	6·98	19	44	43	11·31	24	21	24
25	24·0	8	7·61	7·31	17	43	22	9·46	20	44	27
25		7	6·74		15	38	35				
25		6	5·83		13	29	44				

Various considerations induced the acceptance of a constant velocity along x of 8·5 inches per second. The deviations from it in the increasing velocities are due principally to the disturbance of the fluid by the peculiar method of genesis in that instance employed as most convenient. On this assumption the values of b were calculated by the following formula and placed in the column b', and the values of the angle B found in this manner are written under B′.

In the triangle A B D, $\sin B = \frac{\sin D \times x}{c}$;

whence in the triangle A C D, $b = \frac{\sin D \times x}{\sin C}$.

From what has been said, it follows that there can be no difficulty in calculating the velocity of a body or current from the divergence of the capillary wave.

Let b represent the amount of divergence per foot, the time in which a foot will be described, and consequently the velocity per second, can be obtained by the formulæ which were first given; thus, finding the length of x, and its velocity being known, the absolute time occupied can at once be found, which time is that in which the moving body traverses one foot. In Table II., columns A, B, contain the divergence of the wave expressed in inches per foot, and the corresponding velocity in inches per second.

TABLE XXIV.

For determining the Velocity of Currents or Moving Bodies by Observations of Divergence.

Column A gives the divergence from the path of disturbance measured at right angles to the path, in inches per foot of distance from the disturbing point.

Column B gives the corresponding velocity in inches per second, measured along the direction of the stream or the path of the disturbing point.

Column C contains the angle, which may be observed, at which the wave passes off from the disturbing point, and gives in degrees its divergence from the direction of the stream or the path of the disturbing point.

Column D gives the velocity in inches per second corresponding to the angles in C.

A.	B.	C.	D.
12	12·0	60°	9·81
11	12·62	55	10·37
10	13·49	50	11·09
9	14·16	45	12·02
8	15·38	40	13·22
	17·0	35	14·82
6	19·08	30	17·0
5	22·10	25	20·12
4	27·0	20	24·85
3	35·13	15	32·84
2	51·77	10	48·94
1	102·33	5	97·51
		1	487·10

When the angle of divergence is given, the process is facilitated, as one of the equations used in the previous case has for its sole object the finding of that angle; in Table II., columns C, D, contain the velocities in inches per second corresponding to the given angle of divergence.

Waves of a similar description with those I have here examined, appear first to have been noticed by M. Poncelet, in the course of the valuable experiments made by him and M. Lesbros, which are published in their 'Mémoire sur la dépense des orifices rectangulaires verticaux à grandes dimensions présenté à l'Académie Royale des Sciences,' 16th November, 1829. In a notice in the 'Annales de Chimie et de Physique,' vol. xlvi. 1831, "Sur quelques phénomènes produits à la surface libre des fluides, en repos ou en mouvement, par la présence des corps solides qui y sont plus ou moins plongés, et spécialement sur les ondulations et les rides permanentes qui en résultant," M. Poncelet gives the following description of the phænomena.

"Lorsqu'on approche légèrement l'extrémité d'une tige fine, formée par une substance solide quelconque, de la surface supérieure d'un courant d'eau bien réglé ou constant, il se forme aussitôt à cette surface une quantité de rides proéminentes, enveloppant de toutes parts le point de contact de la tige et du fluide, et présentant l'aspect d'une série de courbes paraboliques qui s'envelopperaient les uns les autres, et auraient pour axe de symmétrie, ou pour grand axe commun, un droit passant par le point dont il s'agit, et dirigée dans le sens même du courant en ce point. L'extrémité inférieure de la tige occupe le sommet de la première parabole intérieure, qui sert comme de limite commun à toutes les autres; le nombre des rides paraît d'ailleurs être infini, et elles sont disposées entre elles à des intervalles distincts qui croissent avec leur distance au point du contact . . . . . . les rides sont parfaitement immobiles et invariables de forme tant que l'état de repos de la tige et de mouvement du courant n'est pas changé; de plus, au lieu de persister plus ou moins après que cette tige a été enlevée, le phénomène disparait brusquement, et à l'instant où le liquide abandonne l'extrémité inférieure de la tige, à laquelle il n'est plus retenue vèrs la fin qu'en vertu de l'adhérence . . . . . . le phénomène s'opere essentiellement à la surface supérieure du fluide.

"...... quand le courant se trouve limité per des parois plus ou moins voisines de la tige, et parallèles à la direction générale des filets fluides, le phénomène des rides se reproduit de la même manière et avec des circonstances sensiblement identiques à celles qui auraient lieu si ces parois n'existaient pas, ou si la masse du fluide était indéfinie; c'est-à-dire que la disposition, la forme et les dimensions des rides sont sensiblement les mêmes, à cela près qu'elles se trouvent brusquement coupées ou interrompues par les parois solides qui limitent le courant comme on le voit représenté, sans éprouver d'ailleurs aucune sorte d'inflexion, de déviation ou de réflexion; l'action de la paroi n'ayant d'autre effet ici que de soulever, à l'ordinaire la surface générale du niveau du fluide . . . . ! ! . . . . le phénomène des rides se manifeste également à l'entour des corps de dimensions plus ou moins grandes, si ce n'est que ces rides s'étendent plus au loin, sont plus larges, plus saillantes, et forment par conséquent des courbes moins déliées et moins distinctes . . . . . . soit que l'on considère les ondulations dans un même profil, soit que l'on considère les ondulations qui se correspond dans des profils différens ou qui appartiennent aux mêmes rides l'amplitude de ces ondulations, c'est-à-dire leur hauteur verticale sera autant moindre, et l'intervalle qui les sépare d'autant plus grand, que les points auxquels elles appartiennent se trouveront plus éloignés . . . . . ces différens systèmes se superposent exactement aux points de leur rencontres mutuelles sans que leur forme soit aucunement altérée . . . . . l'examen attentif de ces changemens de forme et de position des rides produites à la surface d'un courant quelconque par la presence d'un point fine, serait donc très-propre à faire juger, au simple coup d'œil, de l'état même du mouvement en chacun des points de cette surface, et pour chacun des instants successifs où l'on viendrait l'observer . . . . mais cela suppose qu'on a fait à l'avance; une étude beaucoup trop compliquée et trop délicate pour que nous ayons pu jusqu' ici nous en occuper. . . . . on trouve, 1°, que les rides sont imperceptibles quand sa vîtesse est moyennement au dessous de 25 c. per seconde; 2°, qu'elles sont d'autant plus déliées d'autant plus distinctes que la vîtesse est plus grande; 3°, que le nombre des rides se multiplie aussi à mesure que la vîtesse du courant augmente, surtout aux environs du point du contact de la tige; 4°, que les longues branches des rides se réservent de plus en plus. . . . quand la vîtesse surpasse 5 ou 6 mètres les differens rides paraissent se réduire à une seule . . . . ce phénomène est telle (in standing water) qu'on croirait volontiers que le déplacement de la tige n'a d'autre effet que de pousser les rides en avant d'elle et d'un mouvement commun sur la surface immobile."

These are mere points of difference between these observations and my own, which I am disposed to attribute to the peculiarities of condition in which the observations of M. Poncelet were made. His observations appear chiefly to have been made in currents, where it was of course impossible to secure uniformity of motion over the whole surface.

SECTION IV.—WAVES OF THE FOURTH ORDER.

The Corpuscular Wave.

The Sound Wave of Water.

This order of wave I have denominated the corpuscular wave, because the motions by which it is propagated are so minute as to escape altogether direct observation, and it is only by mathematical *à priori* investigation and indirect deductions from phænomena, that we come to recognise its existence as a true physical wave. The motions by which it is propagated are so minute, that it is only by supposing a change in the form of the molecules of the liquid, or of their density, if conceived to be in contact, or an instantaneous and infinitesimal change in the minute distances of the molecules from each other, that the existence of such a wave can be conceived to be possible.

I have not examined this wave by any experiments of my own, and indeed I find that labour to be perfectly unnecessary, for there has been kindly transmitted to me by M. Colladon, a communication of his to the Academy of Sciences, which has been printed in the fifth volume of the 'Mémoires des Savans Étrangères,' in which there is given in great detail, an account of a complete and most satisfactory determination of the elements of this question.

Newton's approximate determination of the velocity of sound in the atmosphere was followed by that of Dr. Young and M. Laplace, who effected a similar approximation for water and other liquids, and finally the complete solution was satisfactorily given by M. Poisson, the velocity being determined both for solids and liquids by the formula

$$c=\sqrt{\frac{\mathrm{P}\,k}{\mathrm{D}\,\varepsilon}},$$

where D is the density of the substance, k the length of a given column, and ε the small diminution of length caused by a given pressure P.

For the determination of the velocity of the sound wave in water, MM. Colladon and Sturm undertook a series of experiments on the compression of liquids, conducted with very ingenious apparatus, and observed and discussed with much accuracy; by this means they obtained values for the quantities P, k and ε, from which the velocity of sound should be theoretically determined.

They obtained for the water of the lake of Geneva the following quantities:—

Assuming $\mathrm{D}=1,\ k=1{,}000{,}000,$

they found $\varepsilon=48{\cdot}66,$

and $\mathrm{P}=(0^{\mathrm{m}}{\cdot}76).g.m=(0^{\mathrm{m}}{\cdot}76).(9{\cdot}8088).(13{,}544),$

whence $c=1437{\cdot}8$ mètres,

being the theoretical velocity per second of the sound wave in water.

A very elegant apparatus was next employed for the direct determination by experiment of the truth of this result. Two stations were taken on the lake of Geneva, the mean depth of water lying between them being about seventy fathoms, and the distance between the stations was carefully determined to be 13,487 mètres, or 14,833 yards, about eight miles and a half, lying between the towns Rolle and Thonon. At one end of this station a large bell was suspended at a depth of five or six fathoms below the surface of the water, and struck by mechanism so contrived, as at the instant of striking to explode a small quantity of gunpowder, and so indicate (during a dark night) to the observer, eight miles off, the instant at which the bell was struck. This sound was distinctly heard by a sort of ear-trumpet lowered in the water at the other end, and so the observations made.

The mean time occupied in propagating the sound from one station to the other as thus determined, was nine seconds and a half, or more precisely 9·4 seconds, giving for the velocity of sound by direct experiment

$$c=\frac{13487}{9{\cdot}4}=1435 \text{ mètres,}$$

the actual velocity of the sound wave thus being found to differ from the theoretical by not three mètres per second.

The velocity of transmission of the wave of the fourth order in water is therefore in English measure about 1580 yards per second, being about one-half more rapid than the velocity of sound through the atmosphere.

DESCRIPTION OF THE PLATES.

Plate XLVII.

Genesis and Mechanism of the Wave of Translation.—Order I.

Fig. 1. *Genesis by impulsion.*—A X is the bottom of a long rectangular channel filled with water to a uniform depth; P a thin plate inserted vertically in the fluid and fitting the internal surface of the channel. It is moved forward from A towards X through the successive positions P_1, P_2, P_3, P_4, P_5, and heaping up the water before it generates a wave of the first order W_4, W_5, which is transmitted along the channel as at W_5, W_6 to W_8, &c., being transmitted with uniform velocity as a great solitary wave, and leaving the water behind it in repose at the original level.

Fig. 2. *Genesis by a column of fluid.*—In the same channel the moveable plate P_7 is fixed so as with the end and sides of the channel to form reservoir A G P_4, containing a column of water G W, raised above the surface of repose of the water in the channel. P_7 is suddenly raised as at P_8 and P_9; the column descends, presses forward the column anterior to P, and raises the surface, generating a wave of translation, which is transmitted along the channel as before. After genesis the volume g_1 reposes on the level g_2, the water in the channel having been translated forwards from P to *kk*; every particle of water in the channel has during the transmission of the wave been translated towards X through a horizontal distance equal to P*k*.

Fig. 3. *Genesis by protrusion of a solid.*—L_1 is a solid suspended at the end of the channel, its inferior surface slightly immersed in the fluid. It is suddenly detached, descends, displaces the adjacent fluid, and generates a wave of translation as in the foregoing methods.

Fig. 4 exhibits the phænomena of genesis, transmission and regenesis, or reflexion of the wave of translation.

Fig. 5 exhibits in four diagrams the motions of individual wave particles during wave transmission. The *first* diagram represents by arrows the simultaneous motions of the particles in different portions of the same wave at successive points in its length. At the front of the wave the particles *a, c, e, g*, taken at equal depths below the surface, are at rest. The wave-length is divided into ten equal parts: at the first the motion is chiefly upwards, and very slightly forwards; at the second, less upwards and more forwards; at the third, still less upwards and still more forwards, and so on; the inclination of the path diminishing to the middle of the wave, where the velocity is greatest and the direction quite horizontal. Behind this part of the wave the particles are to be seen descending more and more with a motion gradually retarded, and at the hinder extremity of the wave they are in repose, as at the front. These motions of the particles of water are rendered visible by minute particles of any kind mixed with the water and nearly of the same specific gravity. Such are the simultaneous motions of the successive particles at different stations along the same wave, as observed in a channel by glass windows placed in the sides and carefully graduated in small squares for the purpose of observation, the side of the channel opposite to the window being similarly graduated. The *second* diagram represents the paths of four particles described during the whole period of transmission of a wave. The wave is transmitted from A towards X. The anterior extremity of the wave finds one particle at *a* and carries it forward through an ellipse to *b*, where it is left by the end of the wave: the same wave translates the particle *c* vertically below *a* through its elliptical path and leaves it at *d* vertically below *b*, and in like manner *e* and *g* are transferred to *f* and *h*. All these paths are semi-ellipses (as nearly as it is possible to observe them), and are of the same major axis; but the semi-minor axis is at the surface equal to the height of the wave-crest, and diminishes with the distance from the bottom of the channel, where it is nil. The *third* diagram exhibits the phænomena of vertical sections during wave transmission: small globules of greater specific gravity than water are suspended at different depths by means of long slender stalks of less specific gravity. These globules are arranged while the water is in repose, in vertical planes at equal distances along the fluid. These vertical planes are, by transmitting the wave, made to approach each other, but still retaining their verticality without sensible disturbance. At the middle of the wave-length they are brought closest, and at the hinder extremity they recede and settle down at their original depth. The *fourth* diagram shows the change of the position of points in the same horizontal planes during wave transmission, particles vertically equidistant in repose remaining equidistant during wave transmission.

Fig. 6. *Genesis of compound waves.*—The first diagram represents the genesis by a large low column of fluid of a compound or double wave of the first order, which immediately breaks down by spontaneous analysis into two, the greater moving faster and altogether leaving the smaller. The second diagram represents the genesis by a high small column of fluid of a positive and negative wave, which soon separate, the positive wave travelling more rapidly, leaving altogether the residuary negative wave. The negative wave is further noticed in another Plate. W_1 is the positive and w 1 the residuary positive or negative wave as generated. W_2 and w_2 represent them separated by propagation.

PLATE XLVIII.

Discussion of Observations on the Velocity of Waves.—Order I.

Fig. 1. Comparison of the observations marked by stars with the formula B, indicated by the parabola A B, of which A X is the axis, parallel to which are measured abscissæ I., II., III., &c., representing the depth of the fluid in inches, the corresponding velocities being represented by ordinates A 1, A 2, A 3, A Y, &c. at right angles to A X. The manner in which the curve passes through among the stars, shows the close approximation of

the results of individual experiments to the formula B adopted to represent them. These are taken from the Table V.

Fig. 2 exhibits a similar comparison for waves of a larger size than the former. See Table IV.

Figs. 3 and 4 show a comparison with the observations, marked by stars as before, with formulæ proposed by Mr. Airy, shown as dots connected by dotted lines, and with the formulæ employed by the author, shown by a continuous black line A B. The eye at once decides whether the black line or the dots and dotted line most nearly coincides with the stars. See Tables VI. and VII.

Fig. 5 exhibits a similar comparison of the velocity of negative waves, as observed in a rectangular channel along A B, and in a triangular channel as shown along A B′. The stars show that the velocity falls below that which the formulæ would assign as due to the depth, especially in the triangular channel. See Tables XI. and XII.

Fig. 6 exhibits the general results of experiments on velocity; the horizontal spaces indicate depths of five inches to each, and the velocities in per second are represented by the vertical spaces which represent each the velocity of one foot per second in transmission of the wave. A B is the line of the formula for a rectangular channel, see Table III.; and A B′ for a triangular channel, see Table XV.

Fig. 7. A X is the surface of water four inches deep; B X represents the successive heights of a wave as referred to in Table II.

PLATE XLIX.

Rediscussion of the Experiments on Velocity.—By the Method of Curves.

Fig. 1. BC, DE, FG, &c. are lines drawn by the eye through the observations of heights of waves shown by the stars; similar lines were drawn through the corresponding observations of velocity. These waves were taken as representing the experiments cleared of errors of observation; they were then collected and laid down in fig. 2.

Fig. 2. A B is the line given by the formulæ employed by the author to represent the velocity of the wave of the first order; the stars are the observations freed in some measure from errors of observation as described above.

PLATE XLIX. (continued.)

Effects of Form of Channel on the Wave.—Order I.

Note.—In a rectangular channel on a level plane the crest of the wave is a horizontal line, parallel to the bottom.

Fig. 3. The section across a channel; $a\,w$ the surface of the water in repose; $a\,d = 4$ inches; $w\,e = 1$ inch; A a the height of the wave-crest $= 1\frac{1}{2}$ inch; B w the height on the shallow side $= 2\frac{1}{2}$ inches.

Fig. 4. A B d the cross section of a triangular channel, A B the crest of the wave, $a\,w$ the level of the water in repose; the angle A d B $= 90°$.

Fig. 5. B $c\,d$ a slope of 1 in 3, being the cross section of a channel $c\,d\,f$; A B the crest of the wave breaking on the sides, where the height of the wave becomes equal to the depth of the water.

Fig. 6. Cross section of another form of channel.

Fig. 7. The sea-beach near Kingstown and Dublin. Common sea waves, W_1, W_2, W_3, W_4, W_5, W_6, break on the ridge d, where their height is equal to the depth of the still water. They generate small waves of the first order, w_1, w_2, w_3, w_4, w_5, &c., which are propagated through the still,

shallow water to great distances, and the intervals between them are left level and in repose.

PLATE L.

Waves of the First Order—Drawn by themselves.

These eight waves are of the natural size, being mere transcripts of the outline of a wave left on a dry surface. The four lower outlines in the Plate were obtained by inserting a dry surface, moved horizontally with a uniform velocity equal to that of the wave, and instantly removing it. The moist outline left by the wave was copied on tracing paper, and transferred without change to the copper-plate. Another method produced the four upper outlines, which were obtained by passing under the wave to be observed another wave transmitted in the opposite direction. These outlines are not therefore to be regarded as copies of a wave, but as transcripts of the outline left by the passage of one wave over another; the crests of both describe horizontal straight lines on the side of the channel, but as every point of one may be regarded as passing over the crest of the other, there is a moist outline left on the side of the channel at the crossing, which outline is simply transferred to the copper, as in the four upper waves. Where a dotted line occurs a blank was left in the outline, which is filled up by the eye. The depth of the water was 2 inches, and the parallel lines in the figure are at 1 inch apart and serve as a scale.

PLATE LI.

These waves are taken in the same manner, but have been reduced from the original outlines to a smaller scale—smaller than the original in the ratio of 2 to 3. The horizontal lines are $\frac{2}{3}$rds of an inch apart, which represents an inch on the full size. The four lowest are taken from waves in water 2 inches deep on a sloping beach, parallel to g X, k X, l X and m X, with an inclination of 1 in 12. The four next are imperfect or compound waves, taken from the outline left by passing another in the opposite direction. The two highest are taken in the same way, one of them in the act of breaking.

PLATE LII.

The Wave of the First Order.

Fig. 1 represents the genesis of a compound wave by impulsion of the plate with a variable force and velocity, which variations have produced corresponding variations on the wave form. After propagation the wave breaks down by spontaneous analysis; the higher part moves forward, as shown by the dotted line, and ultimately leaves the rest behind, so that after the lapse of a considerable period the compound wave is resolved into single separate waves, each moving with the velocity due to the depth.

Fig. 2 represents the phænomena resulting from genesis by a long, low column of water. Instead of genesis of a compound wave, as in the former case of impulsion, the added mass sends off a series of single waves, the first being the greatest: these however do not remain together, but speedily separate, as shown in the dotted lines, and become the further apart the longer they travel.

Figs. 3, 4, 5 and 6 give geometrical approximations to the representation of the wave form and phænomena. In fig. 3, d D d is the length of a small wave divided into ten equal parts; $c\,d$ is equal to the height of the wave, on which a circle is described, and of which the circumference is also divided into ten equal parts. Through these equal divisions of the circle are drawn horizontal lines, which are intersected by vertical lines from each of the divisions of the straight line *d d*, as shown in the figure. A continuous line, passing through these points of intersection, has for its vertical ordinates the versed sines of the arcs of the circle, while its abscissæ are proportional to the arcs themselves. Such a line is the curve of versed sines, and gives a first approximation to the form of the wave of the first order.

Fig. 4 gives a second approximation to the form and the representation of the phænomena of the wave of the first order. A D *d* is taken equal to the length of the wave in the first approximation = 6·28 times the depth of the fluid in repose; on *d c* = the height of the wave, a circle is described and divided into equal arcs as formerly, and thus a dotted line, A C *d*, is formed as before, being the first approximation to the wave form. These equal arcs being taken to represent equal times, the versed sines also represent the rise and fall of the surface of the wave during equal successive intervals of time. But hitherto we have neglected the motion of translation, the horizontal transference of each vertical column of fluid in the direction of wave transmission simultaneous with the vertical motion. Take the length A to A′, such that $A\,A' \times A\,B$ shall $= \frac{V}{b} =$ the volume of water generating the wave divided by the breadth of the fluid. This length, A B, in a small wave will be about three times the height of the wave. Take A A′ as the major axis of an ellipse, of which the minor axis is C D or *c d*, the height of the wave. Let the horizontal lines through the equal arcs of the small circle *c d* be extended to pass through the ellipse A A′, and from the points of division let fall perpendiculars on A A′ on the points 1, 2, 3, 4, 5, 6, 7, 8, 9, then the lines on the axis A A′, viz. A 1, A 2, A 3, A 4, A 5, A 6, A 7, A 8, A 9, A A′ represent the amount of horizontal transference effected during the same time, in which a given particle on the surface is rising and falling through the versed sines of the equal arcs, viz. *d* 1, *d* 2, *d* 3, *d* 4, *d* 5, *d* 6, *d* 7, *d* 8, *d* 9, *d d*. Let us now effect this horizontal transference on each point of the surface on the first wave A C *d*, by advancing the point 1 horizontally through a distance equal to A 1; 2 through a distance A 2; 3 through a distance *a* 3, and so on, and we shall get a curve A′ C′ *d*, which closely represents the form of the wave, and also its phænomena of horizontal translation = throughout the whole depth to A 1, A 2, A 3, A 4, A 5, &c.

Fig. 5 is obtained in the same way as fig. 4, only for a larger wave; where the height is nearly equal to the depth of the fluid, the ellipse is nearly a semicircle. The same ellipse represents also the absolute path of a particle on the surface during wave transmission. Ellipses of the same major axes, but having their minor axes diminishing with their distance from the bottom of the channel, will represent the simultaneous motions of particles below the surface.

Fig. 6 shows a single particle path, and three successive positions of the wave outline in regard to it. The figures 1, 2, 3, 4, 5, &c., give the simultaneous positions of the particle referred to the wave surface, and the same particle referred to the path of the particle. When at 1, 2, 3, 4, 5, &c. in the orbit, the particle is also at 1, 2, 3, 4, 5, &c. in the wave surface. Thus the points which succeed each other towards the right on the path, succeed towards the left on the wave form.

Figs. 7 and 8 represent the genesis of the negative wave of the first order. A solid Q 2 reposes suspended in the fluid, and is suddenly raised out of it. A negative wave is generated and propagated along the channel, as W 1 in figs. 8, 9 and 10. This negative wave of the first order, if it encounter a positive wave of the first order, of equal volume, does not pass over it, but they neutralize each other and are annihilated. If unequal, their difference, positive or negative, alone remains, and is propagated as a wave of the first order.

Figs. 9 and 10 record observations, showing that although the negative wave is in its own order solitary, yet that its existence is the cause of genesis of a group of gregarious waves, or waves of oscillation of the second order; W 1 is a negative wave of the first order: W 1, W 2, W 3, &c., are all waves of the second order. The curved arrows in fig. 9 show the semi-elliptical path of the particles during the transmission of the negative wave. After which, during the transmission of the waves of the second order, the particles describe circles, continually diminishing in diameter as the waves gradually subside.

PLATE LIII.

Waves of the First Order.—Reflexion, Non-reflexion and Lateral Accumulation.

In this Plate a wave of the first order, W_1 R, is represented as incident upon a vertical plane surface immovable at R; *i. e.* the ridge of the wave forms a given angle R_1 W A. After impact at R the wave is reflected, so that the angle of reflexion is equal to the angle of incidence; and when the angle of direction of transmission is great (*i. e.* when the angle of the ridge with the surface is small, not greater than 30°), the reflexion is complete in angle and in quantity. When the angle of direction of transmission diminishes (*i. e.* when the ridge of the wave makes an angle greater than 30°), the angle of reflexion is still equal to the angle of incidence, but the reflected wave is less in quantity than the incident wave. The magnitude of the reflected wave diminishes as the angle of incidence diminishes, until at length, when the angle of the ridge of the wave is within 15° or 20° of being perpendicular to the plane, reflexion ceases, the size of the wave near the point of incidence and its velocity rapidly increases, and it moves forward rapidly with a high crest at right angles to the resisting surface. Thus at different angles we have the phænomena of total reflexion, partial reflexion, and non-reflexion and lateral accumulation; phænomena analogous in name, but dissimilar in condition from the reflexion of heights, &c.

PLATE LIV.

Lateral Diffusion of the Wave of Translation round an Axis.

Figs. 1, 2, 3 and 4 represent a large rectangular reservoir of water filled to an uniform depth with water. It is 20 feet square. From a chamber C in one corner a wave of the first order was transmitted in the direction W 1, W 2; and the observations made which appear in the figures.

In fig. 4 the aspect of the phænomenon is represented. The wave is propagated in the direction of original propagation, which we shall call its axis, with a gradual diminution of its height according to the length of its path along the axis. The observations are probably not yet sufficiently numerous to determine accurately the law of diminution. From this axis the wave spreads on every side. At right angles to the axis of propagation the height of the wave is scarcely sensible, and the diminution of magnitude is very rapid as the line of direction diverges from the axis. The wave is also propagated faster in the direction of the primary axis than in any other direction, so that the wave-crest is elliptic and elongated in that direction.

In fig. 3 the heights of a wave are marked by lines. Each line along W *w* and W 2 *w* represents one-tenth of an inch in height of the wave; so that the height of the wave is indicated to the eye by the number of lines. These observations are made on concentric circles.

In figs. 1 and 2 the same kind of observations is represented, only along straight lines.

Plate LV.

Waves of the Second Order.—Standing Waves in Running Water.

The forms of the waves in these figures are the same as those in figs. 9, 10 of Plate LII., being all cycloidal; with this difference only, that the waves in Plate LII. were moving along the standing water with a uniform velocity, while those in Plate LV. are standing in the running water. The generating course in this case is a large obstacle or large stone in the running stream. On this the water impinges; it is heaped up behind it; it acquires a circular motion which is alternately coincident with and opposed to the stream; the water having once acquired this circular oscillating motion in a vertical direction retains it, the water is alternately accumulated and accelerated, and thus standing waves are formed, as shown in figs. 1 and 2.

Figs. 3 and 4 exhibit a remarkable case of the coexistence in one stream of two sets of waves moving with velocities differing in about the proportion of two to three. On one side of a stream there projected a ledge of rock M, over which fell a thin sheet of water into a large pool, nearly still, without generating any sensible wave. On the opposite side a deep violent current was running round the obstacle with great rapidity. The middle part of the channel was occupied by a large boulder, over which also a stream flowed, generating standing waves with a smaller velocity. These waves are also remarkable for non-diffusion, as they will preserve their visible identity to a great distance without being dissipated.

Plate LVI.

Waves of the Second Order.—Their Mechanism.

All the waves of the second order, whether standing waves in running water or travelling waves in standing water, exhibit the forms of the curves B A B C D in fig. 1. These are cycloids, having for their base the rectilineal distance A C, and for their height the corresponding circles. In the case of standing waves in running water these cycloids represent the actual paths of individual particles of water in the running stream, as shown in Plate LV. In the case of travelling waves in standing water, the circles represent the paths described by the individual particles of water, and the cycloids the visible moving surface presented to the eye. The motion of oscillation in the *upper* half of the circle is in running water, *opposite* to the motion of the stream, and in standing water is in the same direction as the visible motion of transmission of the waves. The figure shows the rapid diminution of the motion of oscillation with the depth. I am indebted for this figure to M. Gerstner, whose theory it illustrates, and I have given it because I find it represent my own observations as correctly as any figure of my own could do. I have only found it necessary in reconstructing his figure to clear it of some slight inaccuracies. The shaded parts on the left show the different forms which given portions of water successively assume during wave motion. The circular orbits are divided into equal portions, numbered 1, 2, 3, 4, &c., to show that the particles of water are in those points of the circles at the same instants the corresponding particles are at the points 1, 2, 3, 4, &c. of the cycloidal paths.

Plate LVI. (continued.)

Waves of the Third Order.—Capillary Waves.

Fig. 2 represents a slender rod inserted in standing water, raising around it by capillary attraction a circular portion of the surface of the fluid. A slow motion gives it the form represented in fig. 3, and more rapid motions, but all of less than a foot per second, give it the forms in figs. 4, 5 and 6; at the velocity of one foot per second the phænomena become those represented in Plate LVII.

Plate LVII.

Waves of the Third Order.—Capillary Waves.

This Plate gives a plan and section on one-half of the natural size of the group of capillary waves generated by a disturbing rod one-sixteenth of an inch in diameter, moving along the surface with a uniform velocity. The section is taken in the direction of the motion of disturbance from A to X, and the same letters refer to the ridges of the same waves in both plan and section. The velocity is one foot per second.

PROVISIONAL REPORTS AND NOTICES OF PROGRESS IN SPECIAL RESEARCHES ENTRUSTED TO COMMITTEES AND INDIVIDUALS.

On the Marine Zoology of Corfu and the Ionian Islands.

By Capt. Portlock, *R.E., F.R.S.*

The author presented a Report of the progress which he had made in the above research by dredging the sea-bed and registering the results of this operation. The spaces at present investigated are of small extent, but the author is preparing to enter on wider areas, in the expectation of presenting hereafter an arranged summary of his observations. [A Committee has been appointed to coöperate with Capt. Portlock.]

On Captive Balloons.

Dr. Robinson stated that he must still report progress, for in a course of experiments so new to him and his coadjutors, they had found it necessary occasionally to vary arrangements which at first seemed satisfactory. In particular, the plan of having the telegraphic wires separate from the moorings of the balloon has been changed, and a single cord, *wormed* as sailors call it with copper wire, is substituted. This, besides being more manageable, will permit a greater elevation to be attained. In one of the trials the balloon received a trifling injury, which however was easily repaired. Dr. Robinson thinks that no serious difficulties are now likely to occur.

Report of the Dredging Committee for 1844.

This Report consisted of two parts; first, of the records of a series of dredging operations conducted round the coasts of Anglesea in September 1844, by Mr. M'Andrew and Prof. E. Forbes, exhibiting the distribution of the marine animals procured in various depths down to thirty fathoms, and the state of the sea-bed in the localities explored. Among the more interesting facts recorded in these papers were the following:—Rolled specimens of *Purpura lapillus*, a shell which lives only above low-water mark, were found in twenty-eight to thirty fathoms water on the gravelly bed of a line of current at the distance of eight miles from the nearest shore. In the same line of current it was found that the few mollusca which lived there, such as *Modiolæ* and *Limæ*, had constructed nests or protecting cases of pebbles bound together by threads of byssus; and one species, the *Modiola discrepans*, had made its nest of the leaf-like expansions of *Flustra foliacea* cemented together.

The attention of the dredgers was directed among other subjects to the distribution of *Serpulæ*, and the results of their researches were confirmatory of the statements recently advanced by Dr. Philippi of Cassel, namely, that no dependence could be placed even as to the genus on the shell of a *Serpula*, perfectly similar shells being constructed by animals of different genera. Thus they found all the *Serpulæ* of a particular form in twelve fathoms water to be a species of *Eupomatus*, whilst exactly similar shells in twenty fathoms proved to be the habitation of a species of the genus, wanting opercula, of which *Serpula tubularia* is the type. All the triangular *Serpulæ* they met with were *Pomatoceros tricuspis*. In twelve fathoms, at the entrance of the Menai Straits, they dredged the shell of *Helix aspersa*, the common snail, covered with barnacles and *Serpulæ*, and inhabited by a hermit crab.

The second part consisted of a series of dredging observations on the Irish coast, drawn up by Mr. Hyndman.

On the Hourly Meteorological Observations carried on at Inverness, at the Expense of the British Association, by Mr. Thomas Mackenzie, *a Provisional Report was presented by* Sir D. Brewster.

On the Forms of Ships.

Mr. Scott Russell reported that the Committee on the form of ships had now completed their labours; that the whole of the tables of the experiments and all the drawings of the forms of the ships were now ready for publication. These tables were so voluminous, and the plates required for illustration were so numerous and expensive, that the question of publication was likely to be attended with some difficulty; but a committee, consisting of the President of the Royal Society, the Dean of Ely, Colonel Sabine and Mr. Taylor, had been appointed for the purpose of making the necessary arrangements. He had now to communicate to the meeting an important addition which had been made to these experiments during the past year. The members of this Section were aware that the former experiments made by the Committee comprehended vessels of many forms and various sizes, from the length of a few inches to ships of 2000 tons displacement; but in all these experiments direct mechanical means of propulsion had been employed and not the force of the wind, and they were therefore regarded as applicable to steam-vessels rather than to sailing ships. During last year, however, most satisfactory experiments had been made in which the propelling force was the wind acting on the sails of the vessel of the open sea. The circumstances in which this experiment originated displayed in a striking manner the advantages conferred by an Association like this on the districts which it visited. The two gentlemen who had conducted this experiment were both Irishmen,—one, Dr. Corrigan of Dublin, having become acquainted through the last meeting in Cork with the experiments of this Association, determined, in building a pleasure-boat, to carry out the principles which had been established by those experiments, and to have his vessel built on that form which was pointed out by these experiments as the *form of least resistance*; he accordingly built a small vessel of about four tons measurement on the *wave-form*, for the purpose of making experiments with it as a sailing vessel; the other gentleman to whom we were indebted for this experiment was Dr. Phipps of Cork, now of London, who had formerly distinguished himself as a naval constructor, and had invented a form of his own which had been attended with great success. At the last meeting in Cork he had become acquainted with the wave-form, and it was under his superintendence that an experimental vessel had been built on the Thames during last summer. The vessel had been tried on the Thames by Dr. Phipps, and subsequently in the bay of Dublin, and the results of the experiments were laid before the meeting in the letters which had been received from Dr. Phipps and Dr. Corrigan. From these letters it appeared that the performances of this small vessel had been surprising. In speed she had already beaten every vessel with which she had been tried, and these included pleasure-boats and yachts, some of them of high reputation for speed and of four times her size. It was of course difficult to conduct experiments of this kind with mathematical precision, but the reports stated that the experimental vessel was not only fast before the wind, but weatherly, dry, stiff and easily worked. The experiments on this vessel were still in progress, and unless she should in future be beaten by some vessel of her own size and of a different form, it would appear from these reports that the wave-form might be adopted with as great advantage in the construction of sailing-vessels as it already had been in the construction of the fastest class of steam-vessels.

Report of the Progress of the Investigation of the Exotic Anoplura. *By* HENRY DENNY, *A.L.S.*

UPON receiving a notification from Sir William Jardine and Dr. Lankester, that the Natural History Section of the British Association had voted the sum of £25 towards an investigation and illustration of the exotic species of *Anoplura*, which they were desirous should be commenced, and that I was requested to undertake the same upon a similar plan to my Monograph on the British *Anoplura*, I immediately proceeded to take such measures as appeared best calculated to enable me to carry out the object of the Section with the greatest benefit to science. With this view, in addition to searching personally for specimens from all the skins of quadrupeds and birds within my reach, I applied, by letter, to various individuals for assistance, several of whom immediately afforded it, and from many others I have the promise of their hearty cooperation as often as the distance at which they are located will allow.

The necessity for depending in a great measure upon foreign aid was soon apparent; first, from the paucity of specimens to be obtained in public or private collections; and secondly, to ensure the exact location of each species as near as possible,—a point of great importance, but which cannot be in all cases depended upon when the parasites are procured from quadrupeds or birds in public collections. The zeal with which my applications were responded to in two instances deserves especial notice,—I allude to the collection of *Anoplura* belonging to the National Museum at the Jardin du Roi having been transmitted for my examination by Professor Milne-Edwards of Paris, and also that belonging to M. P. Gervais of Paris, who was himself engaged on the third volume of Baron Walckenaer's 'Apterous Insects,' containing the *Anoplura*.

From the specimens already received I have made drawings of ninety species; sixty-one of these are engraved on eight plates, leaving twenty-nine still to transfer to copper, besides several specimens which I have yet to examine, and the daily expectation of fresh arrivals from some of my correspondents abroad.

NOTICES

AND

ABSTRACTS OF COMMUNICATIONS

TO THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE,

AT THE

YORK MEETING, SEPTEMBER 1844.

ADVERTISEMENT.

The Editors of the following Notices consider themselves responsible only for the fidelity with which the views of the Authors are abstracted.

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MATHEMATICS AND PHYSICS.

On Diverging Infinite Series. By Professor YOUNG.

THE doctrine of diverging infinite series is a subject upon which very conflicting views are at present entertained. Cauchy, Poisson, and the modern French analysts generally, characterize such series as *false developments*, and reject them accordingly; whilst some of the most distinguished writers of our own country not only advocate the claims of these series to a place in analysis, but even attribute to them, after the example of Euler, finite numerical values.

For instance, it is affirmed that

$$1-3+5-7+9-11+\&c.=0,$$

that

$$1-1.2+1.2.3-1.2.3.4+\&c.=\cdot 4036\ldots.$$

and still more strange that

$$1+2+4+8+16+32+\&c.=-1.$$

In a paper about to be submitted to the Royal Irish Academy, and of which the present communication is a brief abstract, I have examined all the reasonings by which these singular conclusions seem to be established; and I have, I think, shown that such conclusions are in fact at variance with the analytical principles which have hitherto been appealed to in justification of them, viz. common algebraic development, the differential theorem, definite integrals, &c. The following are two of the general principles established in the paper of which this is an abstract:—

1. Whenever an infinite series becomes divergent for particular arithmetical values, what has generally been called the generating function of the series requires a correction, which cannot be disregarded without committing an error infinite in amount.

2. And that so far from such series being, as usually affirmed, always algebraically true, though sometimes arithmetically false—considered in reference to the generating function—on the contrary, they are always algebraically false, though sometimes arithmetically true; true, namely, in those cases, and those only, for which the algebraic function omitted becomes evanescent.

On a Principle in the Theory of Probabilities. By Professor YOUNG.

Let $p_1, p_2, p_3 \ldots p_n$ be the respective probabilities of happening of n independent events; then the following general principle will have place, viz.—

$p_1+p_2+p_3+\ \ldots\ +p_n=$ the prob. of one of the events *at least* happening.
$+$ the prob. of two *at least* happening in conjunction.
$+$ the prob. of three *at least*.
$\vdots$
$+$ the prob. of all happening together.

This general principle, Mr. Young observed, has not hitherto been noticed. It affords an intelligible interpretation of the sum of the probabilities of any number of independent events, and it is, moreover, useful in enabling us very readily to determine certain compound probabilities, when others are already known; thus, let there be but two events; then by the above principle

$p_1+p_2=$ prob. of one at least happening, $+$ prob. of both happening. But the probability of both happening is known to be p_1, p_2,

$$\therefore\ p_1+p_2-p_1\ p_2=\text{ prob. of one at least happening.}$$

Again, let there be three events; then replacing p_1, p_2, p_3, by the combinations $p_1 p_2$, $p_1 p_3$, $p_2 p_3$, we have, by the same principle,

$p_1p_2+p_1p_3+p_2p_3=$ prob. of one of these compound events at least.
+ prob. of two at least.
+ prob. of all three.

But the combination of two of the compound events, at least, is obviously the same as the combination of all the simple events; so is the combination of all the compound events, and the probability of all the simple events happening is known to be $p_1 p_2 p_3$; hence

$p_1p_2+p_1p_3+p_2p_3=$ prob. of two of the events at least happening together,
$+\ 2p_1p_2p_3$;

$\therefore\ p_1p_2+p_1p_3+p_2p_3-2p_1p_2p_3=$ prob. of two of the events, at least, happening together.

Moreover, the probability of one of the events, at least, happening is, by the principle, equal to the sum of the individual probabilities diminished by the expression just deduced, and by $p_1p_2p_3$; that is,

$p_1+p_2+p_3-p_1p_2-p_1p_3-p_2p_3+p_1p_2p_3=$ prob. of one, at least, of the three events happening. And so on.

On the Summation of Infinite Series. By Mr. RAWSON.

This was a mode of combining the theorems of Laplace and Taylor in such a manner as to render series very rapidly convergent, so as greatly to facilitate the calculation of tables, and to render other arithmetical processes more convenient than at present. Mr. Hodgkinson, who communicated the paper, pointed out its important relations to some of the more general processes of integration.

On the Double Square Representation of Prime and Composite Numbers.
By J. J. SYLVESTER, *M.A.*

He first alluded to what had been done by the French mathematicians; and then pointed out the manner in which he thought numbers might be conceived to be composed of squares; and concluded by mentioning some of the advantages which might be expected from this mode of considering them.

On a Theory of Quaternions. By Sir WILLIAM R. HAMILTON, *M.R.I.A.*

It has been shown, by Mr. Warren and others, that the results obtained by the ordinary processes of algebra, involving the imaginary symbol $\sqrt{-1}$, admit of real interpretations, such as those which relate to compositions of linear motions and rotations in one plane. Sir W. Hamilton has adopted a system of three such imaginary symbols, i, j, k, and assumes or defines that they satisfy the nine equations

$$i^2=j^2=k^2=-1,\quad ij=k=-ji,\quad jk=i=-kj,\quad ki=j=-ik,$$

which however are not purely arbitrary, and for the adoption of which the paper assigns reasons. He then combines these symbols in a *quaternion*, or imaginary quadrinomial, of the form

$$Q=w+ix+jy+kz,$$

in which w, x, y, z are four real quantities; and states that he has established rules for algebraical operations on such expressions, and has assigned geometrical interpretations corresponding; so as to form a sort of *Calculus of Quaternions*, which serves as an instrument to prove old theorems, and to discover new ones, in the geometry of three dimensions, and especially respecting the composition of motions of translation and rotation in space.

An Account of the State of the Reductions of the Planetary and Lunar Observations made at Greenwich. By the ASTRONOMER ROYAL.

He announced that the planetary observations from 1750 to 1830 had been reduced by the aid of Bessel's tables, and their places deduced and compared with those given by the best tables for each planet; and this portion was complete. The printing also was nearly finished. The reduction and comparison of the lunar observations, the superintendence of which had also fallen on himself, had been commenced more lately: and this he characterized as by far the most important astronomical work which had been for many years undertaken. The observations were reduced by means of Bessel's tables. The places of the moon deduced from the observations were compared with places computed from Plana's theory, modified by certain corrections introduced by Sir J. W. Lubbock and M. de Pontécoulant. For this theoretical computation, Damoiseau's tables had been used as basis, and small supplementary tables had been computed for the difference between Damoiseau's theory and Plana's corrected theory. Thus the observations, reduced by a uniform system of sidereal tables, would be compared with the best lunar theory in existence. In Damoiseau's tables (edition 1824) the centesimal division of the circle is introduced, which affords much facility in the calculations. A few months would now complete the calculations; but the printing had not yet commenced. Fourteen computers were usually engaged upon them; and by certain improvements which he had introduced into the methods of computing, such as discarding the use of the negative sign altogether, by increasing the quantities from which they could result by a constant number, he had been able, in many instances, to avail himself of the assistance of boys as computers, and thus saved the heavy expense of the more experienced persons. The lunar observations reduced amounted to about 9000; and the computations were made in duplicate, for the purpose of detecting errors.

On the Geodetical Operations of India.

By Lieut.-Col. Everest, *F.R.S., &c., late Surveyor-General of India.*

A series of triangulations on the most magnificent scale has for many years been conducted in India, by Colonel Lambton up to the year 1823, and after his death by Colonel Everest (who had for some years previous been his chief assistant) up to the close of 1843, when this officer resigned the charge to Captain Waugh of the Bengal Engineers, who had been trained by him in the habits of exact observation. As the Court of Directors of the East India Company have, with their characteristic liberality, directed the publication of Colonel Everest's labours, it is unnecessary to enter into the details of the account of them which he laid before the Section, further than to notice a few facts which may give some notion of their probable accuracy, and the immense exertion required to obtain it in such a climate.

Colonel Everest published in 1830 an account of his work from Damargida, the northern extremity of Lambton's arc, lat. 18° 3′ 16″, to Kalianpur, lat. 24° 7′ 12″; but as he then was furnished with new instruments by Troughton and Simms, superior to those which he previously possessed, he repeated all this, and extended it as far as Kaliana, lat. 29° 30′ 49″, where his celestial arc terminates. The terrestrial is carried further to Banog, lat. 30° 28′ 30″, but as this station is in the Himalaya, the attraction of this mighty mountain chain requires to have the zenith distances of stars observed there.

The lengths of these arcs depend on three bases, which were measured with compensation bars similar to those used by Colonel Colby in the triangulation of Ireland; but, on account of the extreme heat of India, applied with even more minute attention than in that instance. The whole operation was conducted under tents, and every thermometer used in the survey was verified by comparison with two standards. The scales employed, two iron of ten feet, and two brass of six inches, have been compared by 101 comparisons, and one of each has been left in India, while the others are deposited in the military store of the Hon. East India Company in Leadenhall Street. The most northern of these bases is near

	°	′	″		feet.
Dehra Dún, in lat.	30	18	18	of	39183·873
The next at Seronj	24	6	50	of	38413·367
The third near Beder	17	54	32	of	41578·536

This last replaces Lambton's base of 1815, the marks of which have been irrecoverably lost. Remeasuring the Dehra base there was found a difference of 2·40 inches, or 0·3 per mile, an extraordinary coincidence considering the wide range of temperature during the process; but it is confirmed by the agreement between the measured and triangulated lengths of two parts of it deduced from the third. When deduced from the second base, the difference is only 7·2 inches. The difference for the third is still less, being only 4·3. The instruments used in the triangulation were a three-feet theodolite, considered Troughton's Capo d'opera, and two three-feet vertical and azimuth circles, which also served for the celestial observations. These were divided on both sides, and had four microscopes, of which two were moveable to any angle. The theodolite and azimuth circles had five microscopes. The referring marks for azimuthal observations and alinements of bases were heliotropes seen through apertures of a quarter of an inch. Each angle of the primary triangles is observed twenty-four times, changing the zero four times, and reversing alternately. Whatever error may remain is distributed among the system according to a theorem of simple application. Azimuthal observations for determining the position of the triangles with respect to meridian, were made at fifteen different stations with the three-feet circles. By careful levelling, reversing between observations and taking both extreme azimuths of circumpolar stars on the same days, an unusual harmony of the results has been obtained. To obtain the amplitudes of the celestial arcs, thirty-six stars were selected for the northern portion of the arc; thirty-two for the southern, in each instance half being north, the rest south of the zenith. Collimated observations were always taken by reversing for each star, and besides, the error of collimation was determined by a collimating telescope. Forty-eight observations were taken of each star, and the moveable pairs of microscopes were shifted into three different positions. The result is that the arc

	°	′	″
From Damargida to Kalianpur is	6	3	55·97
From Kalianpur to Kaliana is	5	23	37·06

The length of these arcs in feet ....1961157·117.

It is, however, to be regretted that this series of triangles, and several others which are described in Colonel Everest's paper, have not been filled up by any secondary triangulation, or made available to any of those social purposes for which accurate district maps are so important. The fault is certainly not with the Court of Directors, who appear from this statement to have been actuated by the most liberal and enlightened views; but wherever it may lie, in Colonel Everest's concluding words, "It is to be hoped that the powers who govern India will see the necessity of taking early measures to cause all these series to be filled up with topographical details in keeping as to accuracy with the material now on record. At present the principal triangles are in many places mere skeletons, instruments of mighty power lying useless. But it seems very clear that without accurate and specific detail, whether as relates to topographical or statistical knowledge, no state can be well governed; and the maps in the possession of the governing power ought for this purpose to be within certain and decided limits of error."

An Account of the Results of the Tide Observations on the Coast of Ireland.

By the ASTRONOMER ROYAL.

He introduced the subject by stating, that during the Ordnance Survey it had been desired to fix upon a plane of reference for elevation, and that Colonel Colby had been desirous of ascertaining whether one invariable plane could be obtained from the observation of tides. For the determination of this, Ireland seemed to present peculiar facilities; for, during the Ordnance Survey, it had been levelled from shore to shore, not only longitudinally, but also across; the result of which was, that round the entire coast many points were marked where the levels relative to one common point, the sill of one of the dock gates in Dublin, were known certainly, to within a very few inches. It was therefore resolved to observe, simultaneously, and for a considerable period, the tides round the entire coast, in order to ascertain whether, from their phænomena, such a certain and readily determined plane could be deduced. In these observations, besides having all the measures of height reduced to this one common standard, it was also determined that all the observers should be furnished with chronometers set to one common time, viz. mean time at the Greenwich Observatory. The first peculiarity observable in the form of the coast was, that while the south-western and western coast was quite open and exposed to the Atlantic, the north-eastern and eastern coasts were, on the contrary, quite embayed, and in particular the channel became very narrow between Donaghadee and Portpatrick, and indeed the entire Scotch coast to the Mull of Kintyre, and the island of Ilay. Stations were carefully selected on all these different seas. Besides this, stations were selected at different points of some of the estuaries, for investigation of the change in the nature of the tide as it proceeds up the estuaries: thus four stations were selected on the estuary of the Shannon. He did not then particularize all the motives which swayed them, but stated generally that twenty-two stations round the coast were fixed upon. On the 22nd of June 1842, they had all their observers at the several stations, and the observations were continued for full two months, viz. until the 26th of August. He need scarcely say, that there were four critical phænomena or periods, in each twenty-four hours, to be noted carefully, viz. the instants of each of the two high waters, and the instants of each of the intervening low waters, and although the season was chosen so that the nights should be short, yet one at least of these four critical phænomena must occur in the night: as it would therefore be too laborious to record at sufficiently close intervals during the entire twenty-four hours, the orders given to the observers were to be at their posts at least half an hour before by any possibility each of these four states of the tide could occur, and then to record every five minutes the actual height. In the night, the registrations were continued only till the tide had taken a decided turn; but in the day, the observations were continued incessantly from the time of beginning before the first critical phænomenon till the tide had taken a decided turn after the third critical phænomenon. At some of the stations, however, the observations were made continuously during the twenty-four hours; to one of them, Courtown, he should have to direct particular attention. The researches of Professor Whewell and of Sir John Lubbock had rendered a close attention to the diurnal and semi-diurnal inequalities of the tides a matter of interest. One of the earliest and most immediate results of these systematized observations was, that the high tide was found to be simultaneous along the entire western and south-western coasts, apparently coming from the west. It was also simultaneous along the eastern coast, but strange to say, with a jump of no less than six hours between these two clearly defined times of high water: so that they were met in the first stage of their speculations by the fact, that there was a difference of no less than six hours between the time of high water at Dunmore (mouth of the Waterford harbour) and at Dublin. This was for a time a puzzle; but from it might be inferred what they afterwards found verified by the observations at Courtown, that a node, or place of no tide, must occur at some intervening place. Another result was, that the diurnal tide came apparently not from the west, but from the south-west. The observations have been grouped and discussed by the new mode pointed out by him in the Philosophical Transactions for 1842, in which the heights were expressed as a function of the times by the following formula:

$$L=A+B\,.\sin\theta+C\,.\sin(2\theta+c)+D\,.\sin(3\theta+d)+\&c.$$

By this method, about 1400 individual tides, observed at all the stations, had been discussed. From this discussion, it appeared that the great tide wave was two days old when it reached Ireland, and that the solar effect exerted in raising the water was about one-third of that of the moon, if the deductions were made from the tides of the more open western and south-western parts of the coast; while the inferences deduced from those of the north-eastern coast, would make it in some places only one-sixth, and in other places about one-half. At some of the stations of the north-eastern coast, an enormous amount of semi-diurnal inequality manifested itself: the semi-menstrual inequality was also found to be considerable there. Another remarkable and unexpected irregularity also resulted from these discussions; which was a difference of no less than one foot between the mean heights of the tides of the western and southern, and the north-eastern coasts; the mean heights of the tides, or values of A, in the preceding formula, being one foot greater for the north-eastern than for the south-western stations. It was also found that the irregularities in the values of A, from day to day, agreed very closely on a long line of coast: and this fact afforded the most demonstrative proof of the accuracy of the observers, for while it manifested itself most distinctly at each of the stations in going round the coast, its amount and its variations were so consistent, as to render it absolutely impossible that it could have resulted from careless observations. He then directed attention to the Courtown station, stating that at the commencement of their labours here the observers had found it impossible to comply with the instructions which had been furnished to them, for it was found impossible to fix upon any of the apparently lawless elevations and depressions of the water as representing the usual semi-diurnal high water or low water. The result was, that of themselves they adopted the prudent course of giving up any attempt at such selection, and observed the height of the tide every five minutes throughout the twenty-four hours. This was a fortunate circumstance, for in consequence of being in possession of these almost continuous observations for such a period, he had been able to make out the law; which under other circumstances might have long continued to perplex. It was found that semi-diurnal tides very small in their actual amount, sometimes not more than a few inches, succeeded each other at irregular intervals; and this was very clearly traced to the influence of the relatively large amount of the solar tide, which, upon examination, was found to be distinctly larger than the lunar tide. With this was mingled a diurnal tide, as large as the diurnal tide at the neighbouring parts of the coast; and also a quarto-diurnal tide, which is found to exist on nearly every part of the coast, and which has its largest value at or near Courtown. The Astronomer Royal said that he was preparing a detailed account of these observations; and he closed by saying, that in reference to the object for which they had been chiefly undertaken, it was now obvious that no fixed plane sufficiently determinate for engineering purposes could be deduced from the phænomena of the tides; at least those observed on the coast of our island or of continental seas.

On the Tides of the East Coast of Scotland. By J. Scott Russell, *F.R.S.E.*

The discussion of the observations was now complete, and they were ready for publication. The chief part of the results had been reported last year, but there remained a few interesting points which had been brought out by the recent discussions. The chief of these was the determination of the *diurnal inequality in the time* of high water, a phænomenon which, as stated by Sir J. Lubbock, has not been discovered on our coasts. This inequality had been manifested in a very prominent form in these observations on the east coast of Scotland; and diagrams were exhibited, in which not only its existence was marked, but its magnitude was measured, and was so great, that the time of high water of successive tides varied, with 25° of declination, as much as from 30 to 80 minutes from this cause. Tables were also given, showing its amount in various ports along the coast. He attributed the detection of this inequality, which had hitherto escaped notice, to the methods of observation which had been employed. His system was to employ, instead of the mere observation of the height and time of still water, or the cessation of rise and the commencement of fall, a continuous series of observations every five minutes on time and height. This series was registered continuously night and day, and the observations were all laid down on ruled paper in a wave curve, from which the observations of time and height were deduced. It was the accuracy of the system of discussing individual wave curves, instead of mere observations of height and time, which had enabled him to detect phænomena that had formerly escaped observation; and he was glad to find that Professor Airy had recommended and adopted that method in his recent observations on the tides of Ireland. Another advantage which the method of observation and discussion of individual wave curves produced, was that tolerably correct tables, for the prediction of tides, might be formed from a very short series of observations. He had found Sir J. Lubbock's tables of the tides of Leith, deduced from many thousand observations, to be very accurate; and from them the tides of Leith were predicted so as to coincide exactly with the phænomena. But, by the method of observation now mentioned, he had formed tables from a few weeks' observation, which coincided quite as accurately with Sir J. Lubbock's tables as those with observation. He concluded by noticing an ingenious Self-Registering Tide-Gauge, invented by Mr. Wood of Port Glasgow, which was so simple as to be constructed to register heights at a cost of two or three pounds, and to register time at a cost of ten pounds. He was happy to add, that tide-gauges of this kind were now being erected at Cork.

On an attempt lately made by M. Laurent, *to explain on mechanical principles the Phænomenon of Circular Polarization in Liquids.*
By Professor MacCullagh.

The author showed that this attempt had not succeeded. M. Laurent supposes the particles of the luminiferous æther not to be simply material points, but to have dimensions which are not insensible when compared with their distances; and on this hypothesis he deduces a system of differential equations, the integrals of which he conceives to represent the phænomenon in question. The integrals given by M. Laurent are, however, altogether erroneous, though this circumstance was not noticed by M. Cauchy in the remarks and comments which he made on M. Laurent's memoir. The true integrals of these equations (supposing the equations to be correctly deduced) were shown by Professor MacCullagh to indicate motions of the æther which do not correspond to the observed phænomena. The account of M. Laurent's theory, with M. Cauchy's remarks upon it, will be found in the eighteenth volume of the 'Comptes Rendus' of the Academy of Sciences of Paris.

On certain points connected with Elliptic Polarization of Light.
By the Rev. Professor Powell, *M.A., F.R.S.*

The peculiar property impressed upon light reflected from metal, and previously polarized at 45° to the plane of reflexion, discovered by Sir David Brewster in 1830, and named by him elliptic polarization, was examined by him chiefly with regard to the effects produced by *a second reflexion* from the same metal,—when the plane polarization is restored, but with its plane changed by a certain angle, which at the maximum characterizes each metal. From this, however, we cannot infer what precise effect is produced by the *first* reflexion alone. It also appears that the ellipticity is small or insensible at small incidences,—arrives at a maximum for most metals at between 70° and 80°, and then decreases again, up to 90°.

The author of this communication has examined some properties of light of this kind by means of the changes in the polarized rings, after *one* reflexion at different incidences.

In all degrees of ellipticity the rings have branches more or less faint corresponding to the degree of dislocation, in all relative positions of the planes of polarization and analysation. At small incidences they are dark and bright in the rectangular positions.

The *position of the darkest branches,* with respect to the plane of reflexion, *changes at different incidences,* in a manner somewhat analogous to what takes place in the reflexion from glass, though it is not at all expressed by Fresnel's law.

At the smallest incidences the position is always *different from* 45°; being determined by an arc considerably *greater* than 45°, as measured from the plane of reflexion.

At greater incidences the arc diminishes; and at the maximum the position coincides with the plane of reflexion. The first-named arc varies with different metals; but the last result is common to all. The intermediate change is more or less gradual in different cases.

The author is engaged in measuring these arcs for a series of metals, but he is not able at present to trace any relation between them and those determined by Sir David Brewster after *two* reflexions.

In the author's paper in the Phil. Trans., 1842, a formula is given for elliptically polarized rings with different retardations: this formula being somewhat generalized, includes an expression for a change of plane; and explains some portion of the phænomena which has not been precisely discussed, especially the peculiar appearance of the rings when the plane of analysation is at 45° to that of polarization.

It does not appear that any theoretical connexion has been yet made out between this virtual change of plane and the retardation which changes with the incidence.

The author is anxious to call attention to this subject in the hope of eliciting from those members who have examined it some results which may enable us to compare theory and observation.

On the Propagation of Waves in a Resisted Medium, with a new Explanation of the Dispersion and Absorption of Light, and other Optical Phænomena. By the Rev. M. O'Brien.

The author notices two different hypotheses which may be made respecting the mode of action of the particles of a transparent medium on the vibrations of the ethereal fluid within it:—the first, "that the transparent substance exerts upon each element of the ethereal fluid forces which depend simply upon the displacements of that element relatively to the contiguous particles of matter:" this will be so, when the amplitudes of the vibrations or maximum excursions of the elements from their positions of equilibrium are extremely small relative to the intervals between the particles of the transparent substance:—the second, "that the forces exerted by the transparent substance upon any element of the ethereal fluid are of the same nature as the resistances experienced by a set of particles moving through a resisting medium, depending not upon the relative displacements, but upon the state of motion of the element;" this will be the case when the amplitudes of the vibrations are large, compared with the intervals between the particles of the transparent substance. The author then proceeds to show that M. Cauchy's equations are founded upon assumptions equivalent to the first of these hypotheses; and gives reasons for not admitting it, stating that though the explanation that author derives of dispersion is satisfactory, the explanation of absorption is really fallacious. He then proceeds to examine, mathematically, the consequences of the second hypothesis, which he conceives has not yet been taken up by any writer upon physical optics, and proceeds to show the probability that it may be of much service in advancing the undulatory theory of light.

Account of a new Proportional Compass. By Oliver Byrne.

By a vernier at the centre, and a means of adjusting a series of points, this instrument enables an observer, by the aid of tables, to multiply, divide, and compare lines, surfaces, solids and angles, with considerable precision.

On the Shape of the Teeth of the Wheels of the Clock in the New Royal Exchange. By E. J. Dent, *F.R.A.S.*

A Notice explaining the Cause of an Optical Phænomenon observed by the Rev. W. Selwyn. *By* Sir David Brewster, *F.R.S. L. & E., Hon. M.R.I.A.*

When a number of parallel black lines are intersected at right angles by other black lines, so as to inclose a number of squares or rectangles, a white spot appears at the intersections of all the lines. In order to discover the cause of this phænomenon, Sir David Brewster made the experiment with the broad opake bars of an old-fashioned window opposed to the light of the sky. Along all the bars he saw a whitish nebulous light, which was the complementary or accidental colour of the black bars seen simultaneously with the bars. The same luminosity was of course seen of equal intensity along all the bars, but at the crossings the intensity of its light was greatest, so as to produce the white spot already mentioned. Now this spot did not arise from any increased effect at the intersections, but from a *diminution* of the complementary luminosity at all other parts of the intersecting lines. This diminution of intensity arises from the action of the white squares or rectangles upon the retina tending to diminish the sensibility of that membrane along the parts corresponding to the black lines, and is always greatest by oblique vision. It is an action analogous to that which takes place when a strip of paper laid upon a green or any other coloured glass disappears when the eye is fixed upon a point an inch or two distant from the paper. Hence the luminous spots are brightest when not seen directly. [The phænomenon thus explained was communicated to Sir David Brewster by the Rev. W. Selwyn.]

An Account of the Cause of the Colours in precious Opal.
By Sir David Brewster, *F.R.S. L. & E., Hon. M.R.I.A.*

This gem is intersected in all directions with colorific planes, exhibiting the most brilliant colours of all kinds. The cause of these colours has never, we believe, been carefully studied. Mineralogists, indeed, have said that they are the colours of thin plates of air occupying fissures or cracks in the stone; but this is a mere assumption, disproved by the fact that no such fissures have ever been found during the processes of cutting, grinding and polishing, which the opal undergoes in the hands of the lapidary. In submitting to a powerful microscope specimens of precious opal, and comparing the phænomena with those of hydrophanous opal, Sir David Brewster found that the colorific planes or patches consist of minute pores or vacuities arranged in parallel lines, and that various such planes are placed close to each other, so as to occupy a space with three dimensions. These pores sometimes exhibit a crystalline arrangement, like the lines in sapphire, calcareous spar, and other bodies, and have doubtless been produced during the conversion of the quartz into opal by heat under the peculiar circumstances of its formation. In some specimens of common opal the structure is such as would be produced by kneading crystallized quartz when in a state of paste. The different colours produced by these pores arise from their different magnitudes or thicknesses, and the colours are generally arranged in parallel bands, and vary with the varying obliquities at which they are seen.

A notice respecting the Cause of the beautiful White Rings which are seen round a luminous body when looked at through certain specimens of Calcareous Spar. By Sir David Brewster, *F.R.S. L. & E., Hon. M.R.I.A.*

By varying the inclination of the spar, the rings increase and diminish, each of them in succession contracting into a luminous spot and disappearing, and then expanding into rings as before. The two rings are produced from the two images formed by double refraction, and hence the light of one ring is oppositely polarized to that of the other. When the ordinary and the extraordinary ray are refracted in lines parallel to the edge of the rhomb, which they are at different incidences, their respective rings disappear. At oblique incidences the rings are highly coloured, and when the dispersive action is small they have a bright silvery whiteness. Sir David Brewster stated that they were produced by minute tubes in the mineral, of which there were many thousands in an inch, and that these tubes were parallel to one of the edges of the rhomb, viz. to that edge to which the refracted ray was parallel when each ring became a luminous spot.

On Crystals in the Cavities of Topaz, which are dissolved by Heat and re-crystallize on Cooling.
By Sir David Brewster, *F.R.S. L. & E., Hon. M.R.I.A.*

Sir David gave a brief notice of the discovery which he had made, about twenty years ago, of two new fluids in the crystallized cavities of *topaz* and other minerals. One of these fluids is very volatile, and so expansible, that it expands twenty times as much as water with the same increase of temperature. When the vacuities in the cavity which it occupies are large, it passes into vapour, and in these different states he had succeeded in determining its refractive power, by measuring the angles at which total reflexion takes place at the common surface of the fluid of the topaz. The other fluid is of a denser kind, and occupies the angles and narrow necks of cavities. The cavities, however, in which the soluble crystals were contained are of a different kind. They (viz. the cavities) were imperfectly crystallized, and thus they exist in specimens of topaz which contain the cavities with the two new fluids; they sometimes contain none of the volatile and expansible fluid, which is doubtless a condensed gas. The crystals which occupy them are flat and finely crystallized rhomboids. When heat is applied, they become rounded at their angles and edges, and soon disappear. After the topaz has cooled, they again appear, at first like a speck, and then recrystallize gradually, sometimes in their original place, but often in other parts of the cavity, their place being determined by the mode in which the cooling is applied.

We understand that Professor Liebig, who regards these fluids and crystals as peculiarly interesting, has made arrangements to investigate their nature, when taken out of their cavities by Sir David Brewster,—an operation of extreme difficulty, owing to the small size of the cavities which contain them, and the rapid disappearance of the volatile fluid, which rises into a drop and contracts into a flat disc, as if it were endued with vitality, finally vanishing and leaving a sediment behind it, which, when breathed upon, again becomes fluid.

On a singular Effect of the Juxtaposition of certain Colours under particular circumstances. By Professor WHEATSTONE, *F.R.S.*

Having had his attention drawn to the fact, that a carpet worked with a small pattern in green and red, when illuminated with gas-light, if viewed carelessly, produced an effect upon the eye as if all the parts of the pattern were in motion, he was led to have several patterns worked in various contrasted pairs of colours; and he found that in many of them the motion was perceptible, but in none so remarkably as those in red and green; it appeared also to be necessary that the illumination should be gas-light, as the effect did not appear to manifest itself in daylight, at least in diffused daylight. He accounted for it by the eye retaining its sensibility for various colours during various lengths of time.

On the same Subject.
By Sir DAVID BREWSTER, *F.R.S. L. & E., Hon. M.R.I.A.*

Sir David Brewster stated that he and Prof. Wheatstone had brought to York separate communications on this experiment, with specimens of the rug-work in which it is best exhibited. Having seen Prof. Wheatstone's specimens, he had been induced to limit his communication to a few observations on Prof. Wheatstone's paper. When Sir D. Brewster came to York, he was not aware of the phænomena taking place with any other colour but *red* and *green*. Prof. Wheatstone had, however, shown him that *red* and *blue* answered equally well; and he had received letters from two ladies in Scotland, who had not only found that *red* and *blue* exhibited the phænomenon, but had both given the probable explanation of their doing so, by ascribing it to the *blue* becoming *green* in the *yellow* light of the candle.

In order to give an explanation of what has been called by some the *fluttering hearts*, from one of the colours having the shape of hearts, Sir David Brewster mentioned an experiment for the purpose of showing that any fixed object will appear to move on the ground upon which it is fixed, when the light which illuminates it is constantly changing its position and intensity. This experiment consists in moving a candle rapidly in all directions, in front of a statue. The varying lights and shadows produce varying expressions, which give the appearance of life and motion to the features of the statue. Now, in the case of the vibrating hearts, the mixture of the *red* and *green*, whether seen as direct or as accidental impressions, produces successions of light and shadow which give the appearance of motion to the figure upon the *red* or *green* ground. This effect is greatly increased by that remarkable property of oblique vision, in which the retina increases in sensibility as the point impressed is removed from the *foramen centrale*. Hence when we look fixedly at one of the vibrating hearts, it nearly ceases to vibrate, while the others, which are seen obliquely, vibrate with greater distinctness. The phænomenon has been stated to be invisible in daylight; but Sir David Brewster mentioned that he had, that morning, found that it took place in daylight, provided the coloured surface was illuminated from a small hole in the shutter of a dark room. The experiment, indeed, he found to fail even in candlelight, if the illumination proceeded from a great number of lights, or from a mass of light producing a *quaquaversus* illumination like that of the sky. He referred also to the effects produced by coloured glasses, and mentioned some facts regarding the unequal absorption of the two colours, which, in drawing conclusions from such experiments, required to be attended to.

On the Accommodation of the Eye to Various Distances.
By Sir DAVID BREWSTER, *F.R.S. L. & E., Hon. M.R.I.A.*

He commenced by giving a sketch of the opinions of several philosophers as to the mode in which the eye acquires its well-known power of accommodating itself to distinct vision at various distances, and the experiments of Troughton and others with a view to determine the question. He then stated that he had ascertained a fact, which he considered to be one distinct step towards the desired explanation, although he must admit that he could not as yet satisfy his own mind with any of the explanations which he had given, nor as yet fully point out how the fact he was about to mention would aid in that explanation. This fact is, that if an object be so placed relatively to the eye as that it is not seen distinctly, distinct vision will be instantly acquired by directing attention to some intermediate object.

Account of a Series of Experiments on the Polarization of Light by rough surfaces, and white dispersing surfaces.

By Sir David Brewster, *F.R.S. L. & E., Hon. M.R.I.A.*

These experiments were made with one or more surfaces of ground glass having different degrees of roughness, and upon paper, snow, and white painted bodies. The state of polarization was ascertained by the polariscope with parallel bands, and its amount measured with the polarimeter which he had invented for this purpose. In polarizing light, the atmosphere acts like a rough surface, and hence these experiments had an application to that new branch of optical meteorology. The degree of roughness in transparent bodies was ascertained by observing the angle of reflexion at which a small circular luminous disc of a given intensity either disappeared or began to lose its distinctness of outline. The general effect of roughness of surface is to diminish the degree of polarization which would have been produced at the same angle by the surface when smooth. In the case of white dispersing bodies, the intromitted pencil, polarized by refraction, is again reflected, and more or less neutralizes the pencil oppositely polarized by reflection.

On the Nature of the Sound Wave. By J. Scott Russell, *F.R.S.E.*

He had determined the existence of certain orders of water-waves governed by different laws, and it was necessary, for the explanation of the phænomena of sound, to determine to which of these orders it was analogous. It was generally supposed that the sound wave was analogous to the waves formed by dropping a stone into the waters of a quiet pool. These were waves of the second order. But his experiments had led him to suppose that the sound wave was a wave of the first order, analogous to the wave of translation in water. This determination would effect a considerable change in our conception and explanation of the phænomena of sound, at present ill understood. For example, the theory of the speaking-trumpet had been given in many forms by different mathematicians; but it was found that the forms assigned by them were nearly opposite, while their effects were nearly identical. This was just what would result from the theory of the wave of the first order. But the whispering gallery was still more inexplicable on the old theory; the dome of St. Pauls was an instance—quite inexplicable on the old hypothesis, but his experiments upon it had proved that the wave of sound did in that case obey implicitly the laws of a wave of the first order, and on that theory its phænomena were completely explained. By considering the sound wave as a wave of the first order, it was now easy to determine the principles on which buildings for speaking and hearing should be formed.

On the Analogy of the Existences or Forces, Light, Heat, Voltaic and ordinary Electricities. By John Goodman, *Esq.*

The author enumerates many general properties in which these *existences* (which term is employed in contradistinction to the opinion frequently received, that caloric, light, &c. are only *effects* resulting from the motion of material bodies) agree. In reference to the "expansion of metals," in which caloric and the voltaic fluid agree, Mr. Goodman describes apparatus by which he has succeeded in showing *expansion* of a column of mercury, by the passage of an electric current through it, while an ordinary thermometer, whose bulb was plunged in the same mercury for an hour, showed no expansion, and consequently received no accession of *caloric*. By increasing the force of the battery beyond a certain point, the thermometer does acquire heat and show expansion of its included mercury, but still the expansion of the mercury in which it is plunged proceeds in a greater degree, and remains five or six degrees in advance. Various other considerations are presented, from which the author concludes, that the existences already named are but varied forms of one fluid, and that caloric in a state of repose is the universal, latent, and primitive fluid of all undisturbed matter.

On a new Process of Magnetic Manipulation, and its Action on Cast Iron and Steel Bars. By the Rev. William Scoresby, *D.D., F.R.S. L. & E.*

Dr. Scoresby found that it was impossible, by the ordinary process, to communicate the full charge of magnetic influence to hard thin bars of steel of the horse-shoe form. Nor was it practicable to magnetize fully thin plates or bars of a straight or ruler form, with a horse-shoe magnet, by the usual processes of manipulation, provided the bars were very hard, or such as were best suited for retaining the magnetic energy, and therefore best for the manufacture of magnets. But he was led, by the theoretic views he holds, to try the effect of interposing thin bars of soft iron between the charging poles of the magnet and the steel bar to be magnetized; this answered effectually, and Dr. Scoresby exhibited to the Section several experiments, whereby, with the old process, the magnetism imparted to the steel bars was very trivial, but by the adoption of the new process, a remarkably strong charge was communicated by one single stroke of the poles of the magnet over the bar, whether of steel or cast iron. And it was stated that such was the efficacy of the process on bars of cast iron, either with an interposed malleable or cast iron bar, that one such cast iron bar received a power of sustaining about twelve pounds.

On a new Steering and Azimuth Compass. By E. J. Dent, *F.R.A.S.*

Contributions to Actino-Chemistry. On the Amphitype, a new Photographic Process.

By Sir John F. W. Herschel, *Bart., F.R.S. L. & E., Hon. M.R.I.A.*

At the end of my paper 'On the Action of the Solar Spectrum on Vegetable Colours,' communicated to the Royal Society in 1842, a process is alluded to (in Art. 230), by which positive pictures are obtained, having a perfect resemblance to impressions of engravings taken with common printers' ink. I had hoped speedily to have perfected this process so far as to have reduced it to a definite statement of manipulations which would ensure success. But, capricious as photographic processes notoriously are, this has proved so beyond even the ordinary measure of such caprice; and, having of late been able to give little or no time to this pursuit, I have thought it preferable to describe the process in a general way, and in a form in which I have found it frequently, and sometimes eminently successful; not so much for the sake of its results, which yet are not wanting in interest or beauty, as for the curious and very complicated photographic habitudes of iron, mercury, and lead which are concerned in their production,—rather, in short, as a contribution to the newly-created science of actino-chemistry, than to the photographic art. Paper proper for producing an amphitype picture may be prepared either with the ferro-tartrate or the ferro-citrate of the protoxide or the peroxide of mercury, or of the protoxide of lead, by using creams of these salts, or by successive applications of the nitrates of the respective oxides, singly or in mixture, to the paper, alternating with solutions of the ammonio-tartrate or ammonio-citrate of iron*, the latter solutions being last applied, and in more or less excess. I purposely avoid stating proportions, as I have not yet been able to fix upon any which certainly succeed. Paper so prepared and dried takes a negative picture, in a time varying from half an hour to five or six hours, according to the intensity of the light; and the impression produced varies in apparent force from a faint and hardly perceptible picture, to one

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* So commonly called, and sold as such; but as I am disposed to regard their composition, their chemical names would be ferro-tartrate and ferro-citrate of ammonia.

of the highest conceivable fullness and richness both of tint and detail, the colour in this case being a superb velvety brown. This extreme richness of effect is not produced except lead be present, either in the ingredients used, or *in the paper itself.* It is not, as I originally supposed, due to the presence of free tartaric acid. The pictures in this state are not permanent. They fade in the dark, though with very different degrees of rapidity, some (especially if free tartaric or citric acid be present) in a few days, while others remain for weeks unimpaired, and require whole years for their total obliteration. But though entirely faded out in appearance, the picture is only rendered dormant, and may be restored, changing its character from negative to positive, and its colour from brown to black (in the shadows) by the following process:—A bath being prepared by pouring a small quantity of solution of pernitrate of mercury into a large quantity of water, and letting the sub-nitrated precipitate subside, the picture must be immersed in it (carefully and repeatedly clearing off all air bubbles), and allowed to remain till the picture (if anywhere visible) is entirely destroyed, or if faded, till it is judged sufficient from previous experience; a term which is often marked by the appearance of a feeble positive picture, of a bright yellow hue, on the pale yellow ground of the paper. A long time (several weeks) is often required for this, but heat accelerates the action, and it is often complete in a few hours. In this state the picture is to be very thoroughly rinsed and soaked in pure warm water, and then dried. It is then to be well-ironed with a smooth iron, heated so as barely not to injure the paper, placing it, for better security against scorching, between smooth clean papers. If then the process have been successful, a perfectly black, positive picture is at once developed. At first it most commonly happens that the whole picture is sooty or dingy to such a degree that it is condemned as spoiled, but on keeping it between the leaves of a book, especially in a moist atmosphere, by extremely slow degrees this dinginess disappears, and the picture disengages itself with continually increasing sharpness and clearness, and acquires the exact effect of a copper-plate engraving on a paper more or less tinted with pale yellow. I ought to observe, that the best and most uniform specimens which I have procured have been on paper previously washed with certain preparations of uric acid, which is a very remarkable and powerful photographic element. The intensity of the original negative picture is no criterion of what may be expected in the positive. It is from the production, by one and the same action of the light, of either a positive or a negative picture according to the subsequent manipulations, that I have designated the process, thus generally sketched out, by the term *amphitype,*—a name suggested by Mr. Talbot, to whom I communicated this singular result; and to this process or class of processes (which I cannot doubt when pursued will lead to some very beautiful results) I propose to restrict the name in question, though it applies even more appropriately to the following exceedingly curious and remarkable one, in which silver is concerned. At the last meeting I announced a mode of producing, by means of a solution of silver, in conjunction with ferro-tartaric acid, a dormant picture brought out into a forcible negative impression by the breath or moist air. The solution then described, and which had, at that time, been prepared some weeks, I may here incidentally remark, has retained its limpidity and photographic properties quite unimpaired during the whole year since elapsed, and is now as sensitive as ever,—a property of no small value. Now, when a picture (for example an impression from an engraving) is taken on paper washed with this solution, it shows no sign of a picture on its back, whether that on its face be developed or not; but if, while the actinic influence is still fresh upon the face (*i. e.* as soon as it is removed from the light), *the back* be exposed for a very few seconds to the sunshine, and then removed to a gloomy place, a *positive picture, the exact complement of the negative one on the other side,* though wanting of course in sharpness if the paper be thick, *slowly and gradually makes its appearance* there, and in half an hour or an hour acquires a considerable intensity. I ought to mention that the "ferro-tartaric acid" in question is prepared by precipitating the ferro-tartrate of ammonia (ammonio-tartrate of iron) by acetate of lead and decomposing the precipitate by dilute sulphuric acid.

P.S. When lead is used in the preparation of amphitype paper, the parts on which the light has acted are found to be in a very high degree *rendered water-proof.*

A Comparison of the Rain which fell at Florence Court, the seat of the Earl of Enniskillen, from July 6th, 1843, *to July 6th,* 1844, *with that which fell at Belfast during the same period. By* W. THOMPSON, *Esq.*

Belfast and Enniskillen are seventy-two miles apart; one towards the east, the other towards the west, of the north of Ireland.

The total depth of rain which fell, was	inches.
At Florence Court	40·6
At Belfast	30·34
Monthly average at Florence Court	3·38
Monthly average at Belfast	2·53
The greatest monthly fall, was	
At Florence Court, in November	6·051
At Belfast, in October	5·046
The fall at Florence Court during October	5·943
The fall at Belfast during November	3·943
The least fall happened in May 1844, at both places,	
At Florence Court	0·041
At Belfast	0·273

The only singular discrepancy which occurred was, that in the month of September 1843, only 0·51 inch fell at Belfast, while at Florence Court, in the same month, 2·759 fell. This, when explained by Lord Enniskillen's steward, who keeps the register, was found to arise from a very heavy fall which took place in one day. The month was generally very dry at both places.

On the Orthochronograph, invented by the late Mr. LOWMAN.

This is a portable instrument for ascertaining the time at any place, by one or more observations, previous and subsequent to the sun's passing the meridian; the circle or circles on the silvered plane being correspondent with the arc described by the sun in its apparent diurnal passage through the heavens. In taking an observation, the upper plate is adjusted so that the reflexion of the sun's rays through the circular aperture cuts at its edge one of the circles on the silvered plate; the time indicated by the watch or clock is then noted, and the instrument left stationary, until the sun's image, after traversing the plate, has returned to the *same* circle, and again the time marked as accurately as possible.

The interval between the two observations will depend on the time when the first is made, and should not be less than three hours: the results thus obtained are added together, and divided by two, a correction made for the alteration of the sun's declination during the interval, and the difference between this result and twelve hours will show the clock's error as compared with solar time; lastly, the equation of time will give the error from mean time.

The Mean Year, or Solar Variation through the Seasons of the Barometer in the Climate of London. By LUKE HOWARD, *F.R.S.* [Plate XLI.]

The variation of the barometer through successive months in any given year has been sufficiently shown to be connected with the lunar influence, by which the tides of the ocean are governed; and this influence, until more fully investigated, will continue to present difficulties in the use of the barometer as a weather-glass—the atmospheric *tides* requiring for this purpose to be set aside while we attempt to prognosticate results from currents of another nature. It may be useful for this purpose to have tables of the variation of the barometer (in connexion with the prevailing winds) *in which the lunar influence is set aside by proper averages.*

Such a set of tables are here presented; the calculations being made upon data to be found in the author's long-published work, 'The Climate of London,' and the years chosen, as most convenient for the purpose, extending from 1813 to 1830. A near approach is thus made to the cycle of 18½ years, in the course of which it is presumed that the effect on our atmosphere of the various positions of the earth and its attendant planet, in relation to each other and to the sun, may balance and neutralize each other. The barometer is thus placed *in immediate connexion with the winds* proper to our climate; and with *the sun's place,* by which these are mainly governed. The artificial year, computed thus, is divided into four seasons, on the principle of the daily mean temperature, and its balance between summer and winter, spring and autumn, as shown in the before-mentioned work. The mean line for the year is placed at 29·831 in., *the average of the whole of the observations.* Winter, as here set out (from Dec. 7 to March 5), has a mean of 29·828 in.; spring (March 6 to June 6), a mean of 29·833 in.; summer (June 7 to Sept. 7), a mean of 29·879 in.; autumn (Sept. 8 to Dec. 6), a mean of 29·782 in.; the whole progressive increase of weight in the previous seasons being now lost by the prevalence of southerly winds, and the decomposition of a portion of the aqueous atmosphere.

The *months* are treated in the paper in succession:—1, as to the barometrical mean of the month; 2, as to the range; 3, as to the average rain; 4, as to the prevailing winds in connexion with these; nearly the whole of the results cited being to be found in the Tables. There are six of these; *two* presenting the daily observations of the direction of the wind during eighteen years, divided into classes and assigned to the several months and years of the cycle, &c.; and *four* comprising the daily mean of pressure, and notations of the wind for each day of the artificial year in detail.

This paper is accompanied (beside the Tables) with two diagrams; *one* formed of the monthly mean results of the pressure and rain, the mean range of the barometer in each being added; *the other* from the daily results above-mentioned. The former presents a remarkable symmetry in the mean pressure and mean rain, proceeding *in opposite directions* through their respective curves; of the latter the author considers that the elevations and depressions of the daily mean of the barometer are here exhibited (on an enlarged scale), *independently of the effect of lunar influence,* in a curve which runs through the year by a regular movement of daily increase or decrease upon the climatic mean; the elevations, coloured *red,* being found where we commonly experience our fair weather, and the depressions, coloured *gray,* in those parts of the year most subject, in our latitudes, to rain and storms of wind*. The equinoxes, it may be observed, are here both marked by the passing of the curve below the mean; the solstices, in *winter* by large depression, going off gradually into the elevation connected with our fair-weather frost; in *summer* by continued elevation, though checked at this precise time by an approach to the mean connected with tropical electrical disturbance and rain. The whole chart may be perused in connexion with the Tables of the Winds (in which are found many beautiful gradations indicative of *system),* to the improvement of our knowledge of this important and hitherto little-explored branch of the subject.

Table of Results to accompany the Monthly Diagram.

1813 to 1830.	Mean of the month.	Maximum of the curve.	Minimum of the curve.	Range of the curve.	Mean depth of rain.	Proportions of the four classes of winds.				Var.
						N—E.	E—S.	S—W.	W—N.	
	in.	in.	in.	in.	in.	days.	days.	days.	days.	days.
January	29·855	29·933	·800	·133	1·84	109	102	130	180	37
February......	29·882	·990	·772	·218	1·51	77	90	142	172	29
March	29·832	[30]·037	·636	·401	1·59	106	89	152	191	20
April	29·788	·911	·597	·314	2·04	118	119	116	168	19
May	29·843	·933	·740	·193	2·24	144	124	123	145	23
June	29·910	·990	·828	·162	2·15	132	78	122	190	18
July	29·853	·981	·752	·229	2·44	79	66	160	230	23
August	29·872	·978	·762	·216	2·17	95	63	156	237	7
September ...	29·860	·991	·731	·260	2·40	114	100	161	151	14
October	29·774	·867	·607	·260	2·49	99	120	153	172	14
November ...	29·767	·924	·550	·374	2·38	82	79	170	194	15
December ...	29·741	·916	·600	·316	2·39	98	100	173	169	18
For the year..	29·831	30·037	29·550	·487	25·64	1252	1130	1758	2199	237

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* These are distinguished in the *Plate* by the shadings.

Daily Observations of the Four Classes of Winds, in each Month of a Cycle.

	1813.				1814.				1815.				1816.				1817.				1818.				1819.				1820.				1821.			
	N—E.	E—S.	S—W.	W—N.	N—E.	E—S.	S—W.	W—N.	N—E.	E—S.	S—W.	W—N.	N—E.	E—S.	S—W.	W—N.	N—E.	E—S.	S—W.	W—N.	N—E.	E—S.	S—W.	W—N.	N—E.	E—S.	S—W.	W—N.	N—E.	E—S.	S—W.	W—N.	N—E.	E—S.	S—W.	W—N.
January	7	8	3	10	11	4	1	7	13	4	3	6	5	6	13	7	2	3	16	4	0	2	14	9	1	9	11	9	6	4	11	8	5	12	9	4
February......	0	0	19	7	9	7	7	4	0	6	9	6	6	3	12	7	0	0	10	16	5	6	7	3	1	4	8	13	10	5	6	6	6	5	4	11
March..........	3	3	10	14	14	6	6	3	0	1	15	12	7	8	11	5	3	4	5	14	3	2	15	10	8	2	8	11	10	2	6	9	4	3	13	9
April	8	8	5	9	4	10	10	7	11	5	2	6	8	12	3	6	16	4	1	7	6	10	8	2	5	10	8	6	7	6	7	10	5	3	6	15
May	4	3	6	11	12	8	2	6	4	2	12	10	8	5	8	10	11	4	6	7	12	5	8	5	7	12	5	7	2	5	14	3	7	3	7	13
June	12	3	4	8	7	7	2	14	7	3	10	9	8	1	6	11	4	6	9	10	1	9	10	9	0	2	15	12	3	2	2	22	19	1	2	6
July	1	2	8	20	1	4	12	14	7	1	5	17	1	1	12	10	0	2	17	12	6	6	7	8	12	1	4	13	9	4	4	10	4	5	6	15
August	8	2	5	14	2	0	12	17	2	2	12	12	5	5	8	12	2	2	18	9	12	3	3	11	13	3	2	13	8	0	14	9	4	7	10	10
September ...	10	5	8	7	11	9	7	3	2	5	13	8	6	5	13	5	12	7	3	4	4	9	8	8	9	5	7	8	8	4	5	12	2	3	9	14
October	8	5	7	7	10	3	10	7	7	5	15	3	1	13	5	8	18	4	6	3	3	10	11	6	8	3	7	13	8	4	10	9	4	6	12	9
November ...	5	5	9	11	9	0	10	9	10	0	8	9	5	4	8	9	1	6	13	9	3	11	11	3	7	1	5	17	8	12	3	4	1	5	15	9
December ...	10	4	8	6	6	8	12	5	5	1	15	9	4	4	10	9	8	5	9	4	9	5	6	8	7	3	15	5	5	10	7	9	0	7	12	12
For the year.	76	48	92	124	96	66	91	96	68	35	119	107	64	67	109	99	77	47	113	99	64	78	108	82	78	55	95	127	84	58	89	111	61	60	105	127

	1822.				1823.				1824.				1825.				1826.				1827.				1828.				1829.				1830.			
	N—E.	E—S.	S—W.	W—N.	N—E.	E—S.	S—W.	W—N.	N—E.	E—S.	S—W.	W—N.	N—E.	E—S.	S—W.	W—N.	N—E.	E—S.	S—W.	W—N.	N—E.	E—S.	S—W.	W—N.	N—E.	E—S.	S—W.	W—N.	N—E.	E—S.	S—W.	W—N.	N—E.	E—S.	S—W.	W—N.
January	5	1	5	20	11	11	4	4	2	0	11	16	9	0	6	15	5	12	2	12	3	3	8	17	1	10	12	8	13	6	1	9	12	6	0	11
February......	1	3	16	8	6	3	6	12	6	10	5	7	2	5	6	15	2	3	14	9	12	6	3	6	4	6	5	14	2	12	3	11	6	2	6	14
March..........	2	1	15	12	5	7	5	14	10	1	6	13	10	11	5	5	8	7	7	9	1	1	12	17	2	2	9	18	11	12	1	4	0	10	5	16
April	10	6	9	4	8	7	4	10	8	6	5	10	8	8	6	8	1	5	2	21	5	7	8	10	5	3	11	11	2	7	11	10	0	6	9	15
May	17	7	2	5	4	7	15	4	14	4	5	8	10	7	10	4	15	6	1	9	2	8	10	8	8	3	2	8	7	9	2	13	2	12	6	11
June	11	9	6	3	13	0	6	9	13	5	8	3	7	3	11	9	11	5	2	12	6	2	10	12	3	6	3	17	3	6	8	12	3	6	7	14
July	3	2	13	11	1	2	13	14	8	5	7	10	9	11	2	9	7	3	11	10	2	5	8	15	1	3	12	15	4	2	11	14	4	6	9	11
August	2	5	4	20	2	1	10	18	9	3	8	11	4	7	9	11	6	6	9	10	7	5	6	13	4	4	7	16	3	4	7	17	2	3	11	15
September ...	12	5	5	8	7	2	7	14	7	5	8	10	3	4	13	10	4	10	9	7	9	5	14	2	6	12	8	4	1	3	11	15	2	1	14	13
October	1	11	11	6	6	9	8	7	3	8	7	13	4	5	9	13	0	11	11	8	4	13	6	8	3	4	7	17	1	2	6	22	4	6	9	12
November ...	5	0	18	5	3	6	12	9	1	2	10	17	2	0	9	19	9	1	6	14	3	5	5	16	2	9	9	10	7	6	4	13	1	6	12	11
December ...	14	7	6	4	1	2	13	15	3	0	12	16	2	6	8	15	5	9	5	12	1	4	14	12	1	7	13	10	15	8	3	4	4	8	4	15
	83	57	110	106	67	57	103	130	84	49	92	134	70	67	94	133	73	78	79	133	55	64	104	136	40	69	98	148	69	77	68	144	40	72	92	158

Tables showing the Relation of the Average Barometer to the Winds and Rain of the Cycle.

TABLE I.

	January.	N—E.	E—S.	S—W.	W—N.	February.	N—E.	E—S.	S—W.	W—N.	March.	N—E.	E—S.	S—W.	W—N.
	in.					in.					in.				
1.	29·853	2	3	2	8	29·845	3	3	4	5	29·732	2	4	6	6
2.	29·867	3	4	3	8	29·863	5	4	4	5	29·700	2	4	7	5
3.	29·871	2	5	5	5	29·857	6	3	4	5	29·654	2	2	7	6
4.	29·885	4	5	5	4	29·870	3	2	5	7	29·712	4	1	8	5
5.	29·900	5	3	4	4	29·882	1	5	6	6	29·636	6	2	3	7
6.	29·924	5	3	5	3	29·858	2	4	5	7	29·689	4	2	7	5
7.	29·883	4	2	3	9	29·872	2	1	6	7	29·672	2	5	6	5
8.	29·933	7	3	2	5	29·880	1	2	7	8	29·653	6	2	3	7
9.	29·878	3	4	4	6	29·990	3	2	6	4	29·730	4	4	3	7
10.	29·880	3	2	4	8	29·985	3	4	4	5	29·795	1	4	4	9
11.	29·804	2	6	2	8	29·980	4	1	6	5	29·849	2	3	6	7
12.	29·878	3	3	7	5	29·952	3	1	9	5	29·887	3	3	4	7
13.	29·836	4	2	6	6	29·889	3	4	4	6	29·915	3	2	4	8
14.	29·826	6	3	3	5	29·917	2	4	3	8	30·001	5	2	8	1
15.	29·823	3	2	1	11	29·924	4	4	4	5	30·037	5	2	5	5
16.	29·827	4	2	3	8	29·874	6	0	6	5	29·971	4	2	4	7
17.	29·850	2	3	5	7	29·860	4	2	6	6	29·946	3	2	2	10
18.	29·812	3	3	6	5	29·843	2	5	6	5	29·914	2	1	1	12
19.	29·816	3	2	8	5	29·862	2	4	6	6	29·860	3	3	2	9
20.	29·800	3	0	1	12	29·772	3	1	6	6	29·822	3	2	4	9
21.	29·845	5	2	3	3	29·792	2	4	6	6	29·813	4	3	4	7
22.	29·868	5	4	5	4	29·874	1	5	5	5	29·780	3	3	7	4
23.	29·865	4	3	4	4	29·869	0	6	3	8	29·807	2	3	5	8
24.	29·825	6	3	6	3	29·910	0	4	4	10	29·789	4	2	6	5
25.	29·860	1	8	2	6	29·900	2	4	6	6	29·884	5	2	4	6
26.	29·832	4	4	5	4	29·880	4	2	4	8	29·934	7	0	5	5
27.	29·836	3	6	5	3	29·880	4	4	3	4	29·922	5	3	8	1
28.	29·855	3	3	5	4	29·818	2	5	4	9	29·875	3	6	4	4
29.	29·850	3	3	3	4						29·873	1	5	7	5
30.	29·876	2	3	5	8						29·930	2	5	5	5
31.	29·864	2	3	8	5						30·018	4	5	3	4
		109	102	130	180		77	90	142	172		106	89	152	191
Mean	29·855					29·882					29·832				
Rain 1·84 in.		Variable, &c. 37 days.				1·51 in.	Variable, &c. 23 days.				1·59 in.	Variable, &c. 21 days.			

TABLE II.

	April.	N—E.	E—S.	S—W.	W—N.	May.	N—E.	E—S.	S—W.	W—N.	June.	N—E.	E—S.	S—W.	W—N.
	in.					in.					in.				
1.	29·886	4	3	7	4	29·925	4	3	5	2	29·933	4	3	6	5
2.	29·836	4	3	1	10	29·870	5	5	2	3	29·896	3	2	5	7
3.	29·891	5	2	3	8	29·790	2	8	3	5	29·854	2	3	2	11
4.	29·871	4	4	3	7	29·800	1	5	5	6	29·834	2	2	5	9
5.	29·800	4	0	5	6	29·742	4	4	5	4	29·857	4	0	5	9
6.	29·780	2	2	6	8	29·740	5	7	8	2	29·936	6	0	3	9
7.	29·800	2	6	3	6	29·804	5	5	5	3	29·928	6	1	5	5
8.	29·749	5	5	4	3	29·800	4	5	6	2	29·918	4	5	2	7
9.	29·709	10	1	5	2	29·846	6	2	5	5	29·908	5	3	3	7
10.	29·780	4	5	2	7	29·855	3	2	6	6	29·957	4	3	1	9
11.	29·682	3	3	5	6	29·864	2	5	4	5	29·990	5	4	5	4
12.	29·729	3	3	3	9	29·812	5	3	4	6	29·980	5	6	4	2
13.	29·771	4	2	3	7	29·771	5	5	4	4	29·920	4	2	4	5
14.	29·775	1	5	3	9	29·764	6	2	3	6	29·883	6	1	5	6
15.	29·723	2	3	5	7	29·830	5	1	8	4	29·905	5	3	6	4
16.	29·700	4	2	7	5	29·903	5	6	3	2	29·903	3	6	2	7
17.	29·769	5	2	4	7	29·890	3	3	3	5	29·951	5	2	3	7
18.	29·826	6	3	3	6	29·882	3	5	4	5	29·910	6	1	3	8
19.	29·852	3	4	2	7	29·880	6	4	3	4	29·860	4	2	5	7
20.	29·828	2	5	3	7	29·866	2	10	3	3	29·864	7	2	3	6
21.	29·724	5	5	4	3	29·861	5	5	1	7	29·925	9	1	3	5
22.	29·649	4	7	4	3	29·872	5	7	3	3	29·951	8	2	3	5
23.	29·597	1	7	4	5	29·808	6	3	3	6	29·963	5	1	3	8
24.	29·700	7	2	5	4	29·762	5	4	3	6	29·977	7	1	4	6
25.	29·814	4	4	6	3	29·786	6	2	5	4	29·958	3	6	3	6
26.	29·834	3	7	2	5	29·841	6	3	4	5	29·897	3	3	6	5
27.	29·869	4	5	3	4	29·913	8	2	1	7	29·857	4	7	2	2
28.	29·884	4	5	5	4	29·897	9	1	3	4	29·868	2	2	6	7
29.	29·896	5	6	3	4	29·933	7	1	3	6	29·888	0	2	8	5
30.	29·911	4	8	3	2	29·913	4	3	3	7	29·828	1	2	7	7
31.						29·911	2	3	5	8					
		118	119	116	168		144	124	123	145		132	78	122	190
Mean	29·788					29·843					29·910				
Rain	2·04 in.	Variable, &c. 19 days.				2·24 in.	Variable, &c. 22 days.				2·15 in.	Variable, &c. 18 days.			

TABLE III.

	July.	N—E.	E—S.	S—W.	W—N.	August.	N—E.	E—S.	S—W.	W—N.	September.	N—E.	E—S.	S—W.	W—N.
	in.					in.					in.				
1.	29·832	4	2	4	6	29·942	2	1	7	7	29·991	8	4	3	3
2.	29·854	2	1	9	5	29·978	2	2	4	10	29·955	4	3	8	3
3.	29·869	4	1	3	10	29·821	1	1	11	5	29·951	5	2	5	6
4.	29·888	3	2	3	7	29·782	3	2	8	5	29·911	5	0	5	7
5.	29·853	3	0	1	11	29·800	4	1	4	9	29·846	3	1	4	9
6.	29·874	3	2	5	6	29·864	2	2	6	8	29·822	1	4	4	7
7.	29·866	2	1	7	8	29·874	1	2	4	11	29·835	3	5	3	7
8.	29·853	3	1	4	10	29·789	0	5	8	5	29·849	2	2	7	6
9.	29·867	1	0	6	10	29·788	3	1	3	11	29·860	5	1	7	4
10.	29·867	0	2	6	10	29·824	3	1	7	6	29·887	3	3	4	8
11.	29·838	1	1	5	11	29·827	1	2	8	7	29·876	4	1	6	7
12.	29·815	1	2	4	11	29·823	1	2	9	6	29·880	2	2	9	4
13.	29·836	3	1	9	5	29·796	2	2	8	6	29·905	2	6	4	6
14.	29·819	2	3	6	7	29·762	2	2	5	9	29·934	3	5	6	3
15.	29·815	2	2	9	4	29·790	3	1	6	8	29·932	4	4	7	3
16.	29·858	5	1	2	8	29·814	2	1	4	10	29·986	4	6	4	2
17.	29·833	1	3	3	8	29·892	3	1	3	11	29·966	4	8	2	4
18.	29·794	1	6	7	4	29·916	3	1	2	11	29·872	6	3	6	3
19.	29·773	0	3	7	8	29·934	5	2	3	8	29·900	2	5	3	7
20.	29·752	1	2	7	7	29·947	5	3	3	7	29·818	5	5	3	5
21.	29·800	1	1	5	11	29·931	4	2	2	9	29·742	5	3	7	3
22.	29·785	2	2	6	8	29·921	4	3	2	8	29·763	5	3	4	5
23.	29·843	2	2	8	6	29·917	6	1	3	7	29·754	6	3	4	5
24.	29·813	4	2	5	6	29·913	5	1	7	5	29·738	2	4	8	4
25.	29·870	2	4	7	5	29·906	5	0	5	8	29·787	3	1	7	6
26.	29·927	4	2	5	7	29·902	6	2	5	5	29·816	3	2	8	5
27.	29·963	7	1	1	9	29·876	2	4	4	8	29·880	2	3	5	7
28.	29·981	4	3	4	6	29·892	3	5	3	7	29·841	3	2	8	5
29.	29·905	1	7	5	4	29·933	4	1	4	9	29·776	5	5	3	5
30.	29·871	5	4	3	6	29·932	4	4	3	7	29·731	5	4	7	2
31.	29·941	5	2	4	6	29·950	4	5	5	4					
		79	66	160	230		95	63	156	237		114	100	161	151
Mean	29·853					29·872					29·860				
Rain	2·44 in.	Variable, &c. 23 days.				2·17 in.	Variable, &c. 7 days.				2·40 in.	Variable, &c. 14 days.			

TABLE IV.

	October.	N—E.	E—S.	S—W.	W—N.	November.	N—E.	E—S.	S—W.	W—N.	December.	N—E.	E—S.	S—W.	W—N.
	in.					in.					in.				
1.	29·720	7	2	3	6	29·827	3	0	2	11	29·634	0	4	5	9
2.	29·802	2	6	3	7	29·824	3	0	6	9	29·634	0	6	5	7
3.	29·843	3	5	7	2	29·774	3	1	6	7	29·623	2	5	7	4
4.	29·853	3	3	7	5	29·840	5	3	3	7	29·676	3	3	4	8
5.	29·861	5	2	4	7	29·831	3	4	5	6	29·636	4	5	2	7
6.	29·814	3	4	4	7	29·755	1	4	5	7	29·722	5	5	4	4
7.	29·781	1	3	8	6	29·747	2	3	5	8	29·740	3	3	6	6
8.	29·855	4	1	6	7	29·747	2	4	5	7	29·727	3	3	5	6
9.	29·860	3	1	5	8	29·728	4	3	3	8	29·803	6	2	3	7
10.	29·818	4	5	6	3	29·783	5	2	5	6	29·800	6	2	4	5
11.	29·773	5	8	4	1	29·769	3	3	6	5	29·860	3	2	4	8
12.	29·807	3	2	8	5	29·727	1	2	6	9	29·822	1	3	9	5
13.	29·836	2	4	6	5	29·670	2	5	5	6	29·855	1	4	4	9
14.	29·867	1	6	3	8	29·550	2	4	5	7	29·834	3	5	6	4
15.	29·827	2	4	7	5	29·581	2	1	5	9	29·790	2	4	5	7
16.	29·747	3	2	6	6	29·663	4	2	5	7	29·710	3	2	7	5
17.	29·770	4	2	5	6	29·836	0	4	8	6	29·600	0	4	7	6
18.	29·748	3	6	2	6	29·923	6	1	7	4	29·623	4	1	10	2
19.	29·631	1	4	6	6	29·924	3	4	5	5	29·700	3	0	11	3
20.	29·607	2	4	6	6	29·831	3	3	8	3	29·674	5	3	7	3
21.	29·643	2	5	4	5	29·764	5	3	4	6	29·700	5	1	3	7
22.	29·650	3	5	6	4	29·760	2	3	6	7	29·715	3	2	8	3
23.	29·702	1	6	2	8	29·774	2	2	5	7	29·706	3	2	4	9
24.	29·714	5	3	7	3	29·756	1	1	7	8	29·724	5	1	7	4
25.	29·754	2	6	5	5	29·821	4	2	6	6	29·767	6	1	5	6
26.	29·796	3	6	3	5	29·840	3	3	4	8	29·740	3	6	5	3
27.	29·802	5	3	5	6	29·840	3	3	4	7	29·778	2	7	5	2
28.	29·827	4	2	4	6	29·753	0	3	11	2	29·800	4	3	5	5
29.	29·796	4	4	4	6	29·700	2	3	8	4	29·866	5	2	6	4
30.	29·705	4	4	3	5	29·664	3	3	10	2	29·822	1	6	5	5
31.	29·776	5	2	4	7						29·916	4	3	5	6
Mean	29·774	99	120	153	172	29·767	82	79	170	194	29·741	98	100	173	169
	Rain 2·49 in.	Variable, &c. 14 days.				2·38 in.	Variable, &c. 15 days.				2·39 in.	Variable, &c. 18 days.			

On the Quantities of Rain received in Gauges at unequal Elevations upon the Ground. By Professor PHILLIPS, *F.R.S.*

The author, referring to three reports which he had already presented, observed that the results arrived at, on York Minster, on the Yorkshire Museum, and on the ground at York, for three years, appeared to require no repetition, and that the reasoning on the results having been generally accepted, he should have thought it unnecessary to recal attention to the subject, unless he had some new facts to communicate. On duly estimating the force of the objections which had been, or might have been, urged against the former experiments, such as the influence of local eddies and currents of wind about the Minster and Museum, and such buildings generally, Professor Phillips resolved to establish a registration of gauges raised into the open air, to various heights, independent of buildings. He had carried on trials of this kind at intervals for more than five years, and after using globular gauges, and various modes of measuring the rain collected, he had finally employed for the last two years, funnel gauges, emptying themselves into reservoirs placed in the ground. Thus some particular difficulties were obviated, and a consistent tally of results obtained. In 1843, from January 9 to October 14, he had obtained registrations of the gauges almost continuously, and in 1844, a similar series from January 1 to September 2, was recorded for him by Mr. Cooke. The gauges are five in number, at 1½, 3, 6, 12, and 24 French feet above the ground. The registrations for the two periods are as under:—

	1843. Inches.	1844. Inches.	Sum. Inches.
24	14·618	9·540	24·158
12	15·419	10·620	26·039
6	15·549	10·640	26·189
3	15·608	10·690	26·298
1½	15·619	10·940	26·559

On these facts the author forbore to comment, having the intention to vary the experiments.

On Simultaneous Barometrical Registration in the North of England. By Professor PHILLIPS, *F.R.S.*

Following out in a limited district the plans of contemporaneous hourly registration, which had been prosecuted by Sir J. Herschel and M. Quetelet for larger areas, the author found the means to combine observations on the barometer, attached thermometer and direction of wind, for twenty-four hours in each month, at nine stations in the north of England, viz. Kendal, Shields, Whitby, Scarborough, Hull, York, Sheffield, Birmingham, Manchester. The observations of five of these stations for six months had been approximately discussed, viz. those of Shields, Hull, York, Sheffield and Birmingham, and the results projected in diagrams. They showed,—1, the remarkable *general* accordance in the forms of the contemporaneous curves at all the stations; 2, the various limits of the deviations from uniformity, never amounting at any two stations to above one-twentieth of an inch; 3, the passage of waves of greater or less pressure in directions nearly corresponding to the path of the wind at the time, and with velocities which appear proportioned to the general movement of the atmosphere at the time, viz. twenty to forty miles an hour.

On the Curves of Annual Temperature at York. By Prof. PHILLIPS, *F.R.S.*

The author stated that the data which he had collected extended over long periods, one series including twenty-five years' registration of the barometer, thermometer, and ancient hygrometer, and that they had been so far discussed as to give interesting results, and that on a future occasion he hoped to present the complete analysis and inferences.

On the Irregular Movements of the Barometer. By T. HOPKINS.

Mr. Hopkins maintained that the *irregular* movements of the barometer arise, not from alterations of surface temperature, but from the condensation of aqueous vapour, and the consequent formation of rain. This, he said, caused local heatings of the atmosphere and considerable reductions of its pressure in the locality, particularly in the colder latitudes. Within the tropics, the barometer does not ordinarily fall as much as in colder latitudes, notwithstanding the abundant rains which take place there, because the condensation occurs, and the temperature is increased at a greater height in the atmosphere, and the reduction of the incumbent pressure in the part is spread over a wider area. The condensation takes place too at an elevation, where the air, from being subjected to inferior pressure, is more attenuated, and the heating is consequently more diffused. Rain is formed in certain latitudes, say at an average height of 3000 feet, where the air has a density proportioned to that height, and where the whole effects of the local heating are confined to an area of moderate extent, thus reducing the pressure of the atmosphere on the barometer in every part of that area in a considerable degree; whilst, in other parts nearer the equator, the condensation which produces rain takes place at an average height of, say 6000 or 9000 feet, where the air is rare in proportion to the height; the heating effects are, therefore, diffused to a corresponding extent, whilst the reduction of pressure at the surface is spread over a wider area. It follows, that with equal amounts of rain the fall of the barometer will be the greatest, and confined to the smallest area in the coldest climates.

On the Diurnal Variations of the Barometer. By T. HOPKINS.

Mr. Hopkins represented that the *diurnal* oscillations of the barometer arise from, first, the condensation of aqueous vapour into cloud, and then from the evaporation of the particles of water that constitute that cloud. He stated, that the morning sun warmed the lower air, and caused it to rise until condensation formed cloud, and liberated heat sufficient to warm a mass of the atmosphere, and thus to cause the barometer in the locality to begin to fall at, say about ten o'clock in the morning, which fall continued until about four o'clock in the afternoon, when condensation ceased. From this time, evaporation of the cloud commenced which cooled the air in the part—made it heavier—and caused the barometer to rise until about ten o'clock P.M., by which time the cloud was evaporated. The cooled and heavier air now descended to the surface, from which it absorbed a portion of heat, and became somewhat warmer. From this second warming of the air, and from a reduction of the quantity of aqueous vapour in the atmosphere, as is evidenced by the fall of the dew-point, the barometer again fell, and from the operation of these two causes, continued to fall until four in the morning; from which time, those general cooling influences that operate in the absence of the sun, caused the barometer again to rise till ten in the morning, thus completing the two risings and two fallings in the twenty-four hours. This was shown to be in general accordance with the tables of the Plymouth observations for three years, and with those made at Madras and Poona. The fact, also found in the Plymouth observations, that the dew-point rose with the temperature until eleven o'clock A.M., when, although the temperature continued rising, the dew-point did not rise higher, showed that the vapour formed during the hottest part of the day was expended in supplying that which was condensed in forming the daily cloud. According to these tables, also, the dew-point at the surface continued stationary until four o'clock P.M., when it began to fall, and continued falling with the declining temperature until the great cold resulting from evaporation ceased. The diurnal fluctuations were also shown to be the least, when the irregular were the greatest (as observed by Mr. Birt), because rain was then produced, and evaporation prevented from cooling the air at the regular diurnal period, and in that way rain prevented the rise of the barometer at that recurring period.

A Year's Meteorological Observations made at Aden. By Sergeant MAYER.

On the Temperature of the Air at various Soundings of Huggate Well, upon the Wolds of the East Riding, Yorkshire. By the Rev. T. RANKIN.

This well is 116 yards, or 348 feet deep. On Saturday, September 21, 1844, at five o'clock P.M., wind N.E.; barometer, 29·750; Fahr. thermometer at the mouth of the well, 51°. Sounded the well with a cord, to which was suspended a self-registering thermometer. At 100 feet deep, 57°; at 200, the same.

On Tuesday, September 24, five o'clock P.M., wind N.E.; barometer, 29·550; Fahr. thermometer at the mouth of the well, 56° in the shade; at 100 feet deep, 57°; at 200 feet, the same. The water at the bottom of the well, about 328½ feet from the top, 50°.

On Wednesday, September 25, at half-past two P.M., wind N.E., but very gentle; barometer, 29·710; Fahr. thermometer at the mouth of the well, 58°; at 150 feet deep, S. R. therm., 56°; at 200 feet, the same; just above the surface of the water, about 327 feet, 50°; water, 49°.

At the same time the water in a wide shallow pond near the well, 57°; in a pump drawn from a cistern filled with rain-water, fourteen feet deep, 51°.

It appears from the last sounding, that the temperature in the shaft of the well is regulated by that of the water. Shaft, 57°; water, 50°; shaft, 56°; water, 49°; being 1° minus in both; difference, 7°.

If the reported depth of the well be 348 feet deep, the water must be 19½ feet. By the cord it was found to be 329½ feet from the top; and from the wet end of the cord, which was supposed to have been at the bottom, having measured 19½ feet + 328½ = 348 feet.

Singular Appearance of a Thunder Storm on Yorkshire Wolds, July 5, 1843. *By the* Rev. T. Rankin.

On July 5, 1843, about two o'clock P.M., the barometer fell from 29·270 to 29·240. Thermometer Fahr. stood at 71°, the highest point for that month. Between four and five o'clock the horizon in the S.W. began to darken; about six distant thunder was heard; betwen six and seven the dark clouds approached the Wolds, the thunder was heard in a continued rolling and growling noise, and the sportive lightning variegated the scene. About eight o'clock the spectacle was sublime and terrific. Volumes of gaseous matter, like the smoke from a park of artillery, rolled along the higher grounds to the N.E. Behind this was a lengthened black cloud rising in an inclined manner, forming an angle of above 45° with the horizon. As the thunder became louder the lightning became more vivid. About nine it reached the summit of the Wolds, preceded by a violent rush of wind; then the broad sheet lightning, followed by loud peals of thunder. Torrents of rain descended in consequence, which terminated in hail and large pieces of ice. About ten o'clock the lightning struck a cottage chimney at North Dalton, and descending, shivered a large splinter from the beam upon which it rests, about a quarter of an hour after the family had retired.

Description of an improved Anemometer. By James Thomas Goddard.

Having after the labour and study of several months succeeded in the construction of a meteorological instrument, designed for keeping an accurate register of the total force of the wind which passes over any station in a given time, such as twenty-four hours, as well as noting the direction, the author offers a slight description of its object and nature. The object sought in the valuable and ingenious anemometer of Mr. Osler of Birmingham, as is well known, is a complete picture of the force and direction of the wind for each day, noting the time to a minute or two of every change in the force and direction of the aërial currents; and for this purpose it is the most perfect and elegant instrument ever placed in the hands of the meteorologist.

The instrument of mine is however intended to show the collective velocity of the wind, or rather the number of miles of air which pass the vane during the twenty-four hours, as well as the respective directions. By this means, by simply reading off the daily results (without calculation) and laying them down on a map of the country, we are informed of the distance and extent to which a wind penetrates into the interior of a large country, thereby giving strictly predictive results; at the same time giving every facility to the investigation of the causes which stop the progress of a wind, or change its direction in the interior of the country, as well as finding numerically the effect of a given surface of air expanded by the rays of the sun. It is easy to perceive, that to procure similar data from the daily sheets of Mr. Osler's anemometer would require a very laborious as well as approximative calculation.

The vane is double, similar to that of Mr. Osler. It is fixed to, and therefore turns with, the perpendicular rod which pierces the ceiling, reaching within a few feet of the ground, resting on the top of a cylinder of wood, round the circumference of which are placed, level with the top, a series of thirty-two glass cylindrical tubes of equal bore, the interstices being neatly filled up with putty or cement.

Each tube represents a point of the compass, and they are intended to hold a coloured fluid, and are therefore sealed over at bottom, similar in fact to test tubes, only considerably larger; they are graduated so as to indicate the height of the liquid within them, which height depends directly on the number of miles of wind which has passed the vane in the twenty-four hours. Above the circle of tubes is an apparatus which deposits the liquid into them; there is also a contrivance, which is affixed to the pressure plate, by means of which the fluid is deposited at a variable rate, but always depending on the force on the pressure plate at the time. Thus, if for instance a drop per minute answered to a wind of one mile per hour, two drops per minute would show a velocity of two miles per hour, fifty drops a minute a velocity of fifty miles an hour, and so on; and as the tubes collect the daily deposit, by simply reading off the daily deposit or elevation of the fluid, and noting the respective tube or tubes in which it is found, we have at once the number of miles of air which has passed the station as well as the direction.

To describe the apparatus by which the quantity of fluid is regulated, so as to flow in proportion to the wind's velocity, would require a diagram; but the general character is sufficiently obvious to give the meteorologist a good idea of it. Mr. Osler's clock is superseded by clepsydral arrangements, and the spiral spring for the pressure plate is replaced by the natural spring of water, which is far superior to any artificial spring. In concluding, the author urges on the Members of the Association the importance of *instituting experiments,* to be made with a view of correcting our constants relating to the *velocity of wind* appertaining to a given force, as the errors of the tables will much interfere with extensive computations.

On an Instrument called a Barometer Pump, for filling Barometer Tubes in vacuo. By Lieut.-Col. EVEREST, *F.R.S.*

This was a single acting air-pump, so arranged as to exhaust the air from the tube to be filled, while a capillary tube, dipping into a reservoir of mercury, and curved at the end next the tube, dropped the mercury into the tube as it rose above the bend (after the exhaustion had been carried as far as possible), by dipping a glass rod into the reservoir. The mercury as it comes into the tube is heated to a temperature sufficient to boil it, and it is desiccated by a bottle of strong sulphuric acid, which is made to communicate with the canal into which the tube to be filled and the capillary filling tube are luted. Col. Everest mentioned, that the best material for the valves of an air-pump was the swimming bladder of a fish.

Account of an Attempt to establish the Plastic Nature of Glacier Ice by direct Experiment. By Professor J. D. FORBES, *F.R.S. L. & E.*

These experiments were made in the month of August last upon the Mer de Glace of Chamouni, with the view of establishing that the increasing velocity of a glacier, from the side towards the centre, takes place (when the declivity is not very great) by the insensible yielding of one portion of the ice past another, without great rents at measurable distances producing discontinuity in the motion. The only permanent marks left by such differential motion are the veins, or blue-bands, to which the author has, in his published writings, attributed such an origin.

A transverse line was drawn partly across the glacier in the most compact part which could be found, which was quite devoid of open crevices for a considerable space. The theodolite was planted over a fixed mark in the ice at the extremity of this line nearest to the lateral moraine of the glacier; and the relative, or differential velocities of the parts towards the centre were determined at short intervals, and have been projected in a curve. This curve was shown to the meeting. It is evidently a continuous curve, convex towards the valley, and not a zigzag motion, such as must have resulted from distinct rents parallel to the length of the glacier. The length of the line, originally straight, whose *deformation* was observed, was 90 feet, and the ordinates of the curve were determined by accurate measurements at forty-five stations two feet apart. The experiments on the continuous flexure of the transverse line were extended over a longer period, at points 30, 60, 90, 120, and 180 feet from the theodolite, with similar results.

The author concludes,—1st, that the sliding of the mass of the glacier over itself by insensible gradations cannot be denied, and that it is sufficient to account for the observed excess of progress of the centre above the sides of the glacier; 2nd, that this differential motion takes place in the direction in which the veined structure exists, and that it is impossible not to consider the one phænomenon as dependent on the other.

Experimental Inquiries into the Falling-off from perfect Elasticity in Solid Bodies. *By* EATON HODGKINSON, *F.R.S.*

At the Cork Meeting of the British Association, Mr. Hodgkinson laid before the Section the results of some experiments, the object of which was to show that no rigid body is perfectly elastic; the slightest change of form in a body producing a permanent alteration in it, however small. He endeavoured to show, too, that in experiments on the deflexion of rectangular bars of cast iron, and some other materials, the defect of elasticity, denominated the set, varied as the square of the weight laid on, nearly. It might, he stated, be inferred, too, that the set varies as the square of the deflexion, since the deflexion is as the weight nearly, though it varies in a ratio somewhat higher than that.

In rectangular bars bent so as to strain them in a small degree only, the particles are equally extended and compressed on the opposite sides of the bar; but in bars whose section is of the form $\mathrm{A}\underset{\mathrm{C}}{\top}\mathrm{B}$, the deflexion arising from the flexure of the plate A B and the extension or compression of the part C, varies in a higher degree than as the square of the weight, and in these the set varies nearly as the square of the deflexion.

Mr. Hodgkinson stated that, soon after the Cork Meeting, he had received, from a very intelligent writer, a letter on the subject of the communication here described. In this letter considerable doubt as to the correctness of his conclusions was expressed, and it was suggested that the facts might probably be accounted for by attributing them to friction between the ends of the beam and the supports on which it rested, a matter which had been investigated by the Rev. Professor Moseley, in his able work on the Mechanical Principles of Engineering and Architecture (Art. 389).

Mr. Hodgkinson felt convinced that the causes mentioned in the letter were not the right ones, but thought it incumbent on him to obviate, as far as possible, all objections, and to show that friction was not the cause of the results observed.

In his former experiments the weight of the bar was neglected, as it was very small compared with the weight laid upon it; and the deflexions and sets were measured from that position which the middle of the bar had taken in consequence of its own weight. The friction upon the ends of the bar, from the supports on which they rested, had likewise been neglected; and the quantities of the sets, usually very small, had been measured by an instrument (a long wedge graduated along the side); and although this was good comparatively with some previously used, it did not admit of all the accuracy which was required.

He had, therefore, an apparatus constructed to remove these defects. In this apparatus, the bar or body bent is laid upon its edge or smallest side, and the force to bend it acts horizontally. The ends of the bar are supported horizontally and vertically by friction rollers, and the deflexions and sets are measured from the centre of the "straight edge," in which screws resting on the ends of the bars opposite the rollers are inserted. The sets, and the smaller deflexions, are measured by a micrometer screw, in the centre of the straight edge, capable of measuring distances as small as $\frac{1}{10000}$th of an inch. In this apparatus the flexure of the bar, being horizontal, arises wholly from the weight laid on, and the friction must be almost insensible. The admeasurements of the sets, Mr. Hodgkinson stated, were as accurate as the light of a candle, in addition to bright day-light, would enable the observer, using the utmost care, to judge. Great care was taken to have the ends of the bars well-supported during the experiments, and when a bar in its natural state was not perfectly uniform, but in some degree twisted, iron wedges filed to the exact form were made and fastened to the ends of the bar, that it might rest firmly against the rollers. The length of the bar between the rollers supporting the ends was six feet six inches; and its depth in different materials varied from $\frac{3}{10}$ths of an inch to one inch, or a little more, in the direction in which the bar was bent. The utmost attention was paid to ensure accuracy, and the time taken up by an experiment was usually from three to five hours, but in some cases a whole day.

The principal source of error arose, apparently, from the difficulty and almost impossibility of keeping the long flexible bars operated upon perfectly free from vibration, in the neighbourhood of a large manufactory. Another source of small error might arise from the pressure of the screws at the ends of the straight edge against the ends of the bar, these being held by light springs to keep them always in contact; but this was avoided by removing them in the experiments on some of the most flexible bars, as those of steel and wrought iron.

With this apparatus many experiments on bars of different materials have been made, and the deflexion and set from different weights obtained, the leading results from which are below.

In ribs of soft stone, each sawn seven feet long, four inches broad, and about one inch thick, bent in the direction of their least dimension, the mean deflexion was obtained from the same weight laid gently on about four times, for three minutes each time; and after the bar had been unloaded each time for five minutes, the set was observed. The mean results in different experiments are as follow:—

	Weights laid on. lbs.	Sets produced. inch.
Experiment 1.	7	·006
	42	·170
	14	·026
	42	·170
Experiment 2.	7	·0099
	28	·149
Experiment 3.	14	·0369
	28	·1298
Experiment 4.	7	·0099
	28	·1271
Experiment 5.	3½	·0087
	14	·0879
	7	·0280
	14	·0879

Seeking from above for the power n, of the number expressing the weights to which the sets are proportional, we have (in Experiment 1), $7^n : 42^n :: \cdot006 : \cdot170$; whence we obtain $n=1\cdot866$; and from the other experiments we have n successively equal to 1·957, 1·810, 1·840, 1·709, 1·668, 1·650; the mean from the whole giving $n=1\cdot786$. Whence it appears, Mr. Hodgkinson observes, that stone differs in this respect but little from cast iron, the sets varying nearly as the squares of the weights laid on.

In wrought iron and steel the sets seem to follow a different law, but the examination of these metals has not been completed. In these, as in materials of every description tried, the weights, however small, seemed to produce a permanent set; no body recovering of itself its original form after a change of figure had been produced in it.

If a small weight was laid, without any acceleration, upon a bar of any material a number of times successively, the set was found to be increased each time. Mr. Hodgkinson read to the Association results of this kind from stone, cast iron, hard and softened steel. He had sought for the longitudinal extension and set in long bars of cast iron, as well as of wrought iron; but he was not prepared to give the final results.

It was found that in all cases where a strain had been applied to a body, it showed for some time afterwards a tendency to return towards its original form, though it never would be able to arrive at it. This was particularly evident for a few minutes at first, and on that account the sets were usually taken twice or more, as at the expiration of one minute and five minutes, and sometimes half an hour after unloading; but after five minutes they seldom altered much.

In all materials, the sets produced by the smallest weights tried, seemed to be nearly in the ratio of the weights; but as the small friction of the apparatus would make a sensible addition to the set due to the material from such small strains, he drew no conclusions from the fact.

Mr. Whitworth exhibited an instrument for measuring bodies to a very minute degree of accuracy. It consisted of a strong frame of cast iron, at the opposite extremities of which were two highly finished steel cylinders, which traversed longitudinally by the action of screws one-twentieth of an inch in the thread; these screws were worked by two wheels, placed at opposite extremities of the frame, the larger of which had its circumference divided into five hundred equal parts; the ends of the cylinders, at the places were they approached each other, were reduced to about a quarter of an inch, and their hemispherical ends were highly polished. To measure with this instrument, the large circle was brought to its zero, and the body to be measured, being placed between the cylinders, the small circle was turned until the two cylinders touched the opposite sides of the body, which being removed, and the large circle turned until the ends of the two cylinders were brought to touch the turns and parts of a turn required for this, it gave the breadth of the body which had been interposed to the ten-thousandth part of an inch, and since the one-tenth of one of the divisions could be readily estimated, the size of the body could be thus estimated easily to the $\frac{1}{100,000}$th part of an inch. Mr. Whitworth stated, that in the accuracy required in modern workshops, in fitting the parts of tools and machines, the two-foot rule heretofore in use is not by any means accurate enough; his object was to furnish ordinary mechanics with an instrument which, while it afforded very accurate indications, was yet not very liable to be deranged by the rough handling of the workshop; and he conceived this instrument secured those advantages. It surprised himself to find how very minute a portion of space could be by it, as it were, felt. By it the difference of the diameters of two hairs could be rendered quite palpable.

Communications from Norway, presented by JOHN LEE, *LL.D., F.R.A.S.*

A paper by J. R. Crowe, Esq., Consul-General of Her Britannic Majesty for Norway, dated Christiana, 29th May 1844, entitled, 'General Observations on the Climate of Norway and Finmark, with some remarks on the Geography, Geology and Agriculture.'

Also, a table of meteorological observations, taken at Christiana, north latitude 59° 54′ 1″, east longitude 10° 45′, during the year 1843, and the barometrical and thermometrical means for each month.

A letter, dated Alten Observatory, 20th April 1844, from J. H. Grewe, Esq., detailing the difficulties which he had to encounter on ascending the mountain called Storvandofjeld, on the 1st December 1843, to fix a minimum thermometer on its apex, and of his second expedition on the 17th of April 1844 to examine it, and bring it down to Alten; the lowest degree of cold on the top of the mountain during the winter having been 35° longitude, and the lowest degree at Alten 27°, a difference of 8° between the two places.

Also an account of a fine parhelion which he beheld at 5^h 50^m A.M. at a height of about 1500 feet, with a drawing.

A paper by John Francis Cole, Esq., Member of the Literary and Astronomical Society of Alten, on the Aurora Borealis, as seen at that place, and which has been drawn up from a series of observations.

A paper by John Francis Cole, Esq., of Alten, on a remarkable and sudden fall of rain which took place with a clear sky on the 6th of May 1844, and which, in his opinion, has much analogy with a fall of rain from a clear sky observed by Professor Wartmann at Geneva, on the 31st of May 1838. Also an observation on the evaporation of the ice on the 3rd of May 1844, at Alten.

Meteorological tables :—

1. Results of the meteorological observations made at Alten observatory, by Messrs. J. H. Grewe and J. F. Cole, during the year 1843.
2. A table showing the approximate forces of the winds for each month and for the year, with the means of each month and the year, the latter including calms.
3. A table showing the number of days in each month and in the year on which it was calm, windy, and from what quarter.
4. A table showing the number of days the different clouds were visible in each month and in the year.
5. A table showing the approximate forces of the driving of the clouds for each month and for the year, with the means of each month and the year, the latter including *imperceptibles*.
6. A table showing the number of days in each month and in the year on which the clouds were not observed to drive, as well as on which they were observed to drive, and from what quarter, and the number of times the aurora was visible (61).

CHEMISTRY.

On the Mineral Springs and other Waters of Yorkshire. By W. West.

The results of analysis of the waters of Harrogate and many other places were detailed with great minuteness, and the districts from which the waters were collected described.

Account of the Phosphorite Rock in Spanish Estremadura.

By Professor Daubeny, *F.R.S.*

In conjunction with Captain Widdrington, R.N., he had last summer undertaken to explore this rock. He stated its occurrence in one solitary mass, penetrating clay-slate, the dimensions being at most sixteen feet in width, its length along the surface of the ground extending to about two miles, whilst its depth is unexplored, but certainly considerable. He stated its composition to be, about 80 per cent. triphosphate of lime, and about 14 fluoride of calcium, and pointed out the final cause of the secretion of so large a mass of both these substances in the older rocks, as being intended to supply two necessary ingredients for bones and other animal matters. He stated his having detected fluorine in all the bones and teeth of recent as well as of older date which he had examined, and suggested, that as a rock of such a composition could hardly fail to be useful as a manure, if it were found in an easily accessible locality, it would be worth the while of geologists to search for veins of this mineral in the older formations of this and other countries, where there might be a greater facility of transport.

On the Theory and Practice of Amalgamation of Silver Ores in Mexico and Peru. By J. C. Bowring.

After noticing and refuting the hypotheses by which the operations for the amalgamation of silver ores in the countries mentioned have been conducted, the author proposes the following explanation.

The presence of mercury being necessary, not merely as a means of collecting the particles of silver disseminated through the ore, but also as a chemical agent, the action of bichloride of copper upon it must be considered.

By this action, which takes place instantaneously, a protochloride of both metals is formed, and that of the copper, by absorbing oxygen from the atmosphere, becomes converted into an oxychloride, which by giving up its oxygen to the sulphur combined with the silver, leaves this in a metallic state and free to amalgamate with the mercury. This is proved by boiling native sulphuret of silver with oxychloride of copper* in a solution of common salt, when metallic silver will be obtained; or as a more practical experiment, by mixing some rich ore with these materials and mercury at the ordinary temperature; in about an hour the whole of the silver will have become amalgamated, when on separating all the soluble salts by filtration, and the addition of chloride of barium, sulphate of barytes will be precipitated, equivalent in quantity to that of the sulphur which has been acidified; it will thus be made evident that the sulphuric acid can only have been formed by the decomposition of the sulphuret of silver, and could not have existed if this metal had become combined with chlorine, according to the theory hitherto received.

The action of oxychloride of copper in the reduction of silver ores seems to be continuous, and its theory thus offers some analogy to that of the manufacture of sulphuric acid: by giving up its oxygen to the sulphur previously combined with the silver, the oxychloride of copper is converted into a protochloride; and this into a bichloride, by the action of the chlorine, which is evolved by the decomposition of the salt when attacked by the sulphuric acid that has been formed. This bichloride is again decomposed by the mercury, and first a proto- and then an oxychloride of copper are formed: the sulphur of the silver becomes acidified, and the action is continued in the same manner until the whole of the metal is amalgamated.

By the direct use of oxychloride of copper, instead of forming it in the "tortas" by means of the sulphate, as in the usual method, the author has obtained very advantageous results, not only as far as regards a great saving of time, labour and materials, but also by the extraction of a much larger quantity of silver than could possibly be got out by the old process.

The loss of mercury, although greatly diminished by its means, cannot indeed be entirely avoided, as is evident from the theory of the operation; but the principal advantage derived from this method consists in the larger amount of silver produced; and this is a very important point to be considered, when on a moderate calculation at least the value of half a million sterling per annum is left in the ore, and thus irretrievably lost, in Mexico alone, through the imperfections of the usual process of amalgamation. In order to protect entirely the mercury from being attacked, it would be necessary to have in contact with it some metal more readily oxidizable, as zinc, tin, or lead; but any of these bodies would decompose the oxychloride of copper, and thus destroy its action on sulphuret of silver; perhaps a very weak solution of carbonate of soda or potash would not have this effect, and would serve to neutralize the acid that is disengaged.

The author then treats of the proper mode of forming the oxychloride of copper to be employed in the reduction of silver ores; points out the practical good effects which have resulted by application of his theoretical views, and shows the importance of a full consideration of the subject by statements of the great loss of silver which is experienced by following the old routine, unaided by science.

At Guenaxato this loss is estimated at 10 per cent.; Fresmetto, 28; Zacatecas, 35 to 40; nor is this the extreme case.

On Mr. Phillips's *Method of discovering Adulteration in Tobacco.*
By Joseph Bateman, *LL.D., F.R.A.S.*

The basis of this plan is the ascertainment and comparison of the relative proportions of soluble and insoluble matter in tobacco; water being the solvent. Numerous experiments have proved that every kind of vegetable matter has a determinate portion, which is soluble in water; thus rhubarb-leaves range from 18 to 26 per cent., and horse-radish, lettuce, oak, elm, and many others, have their definite limits. This amount, with reference to tobacco, in no case exceeds 55 per cent. of the tobacco: and thus if tobacco be adulterated with matter soluble in water, the extractive or soluble part is increased, whilst the ligneous and insoluble matter are correspondingly de-

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* This oxychloride of copper must be partially soluble in a solution of salt, as that prepared in the common way would have no effect.

creased. A sample of genuine tobacco, by careful manipulation, affords 50 per cent. of soluble matter, and when another portion of the same tobacco has been mixed with 15 per cent. of soluble matter, the sophisticated article can contain only 85 per cent. of tobacco; and it would be found by experiment to afford to water 57·5 of soluble, and 42·5 of insoluble matter, thus affording proportions for calculating the actual amount of adulteration introduced.

On the Limestones of Yorkshire. By W. Lucas.

The limestones may be comprised under the four following classes, viz.—

1. The Mountain Limestone.
2. The Magnesian Limestone, including both the upper and lower beds.
3. The Oolitic Limestone.
4. The Chalk.

1. The *Mountain Limestone* is developed to a great extent in the district of Craven and in other parts of the north and north-west portions of the county. It is of a dark gray colour, and hard, breaking with a species of conchoidal fracture. Its specific gravity is about 1·70. According to analysis, the following are its principal constituents, viz.—

Carbonic acid	43·00
Lime	55·50
Foreign matter	1·50
	100·00

It thus appears to contain about 98·50 per cent. of carbonate of lime, and consequently would appear to be an excellent limestone for the purposes of agriculture.

2. The *Magnesian Limestone*.—The lower portion of this formation is found in immediate succession to the coal measures. It is of a yellowish-white colour, and breaks with a dull earthy fracture. Its specific gravity is about 2·64.

A specimen from Conisbrough, near Doncaster, gave the following as its chief constituent ingredients, viz.—

Carbonic acid	46·50
Lime	35·00
Magnesia	17·75
Red oxide of iron	0·75
Insoluble matter	......
	100·00

Another specimen from the village of Weldon, adjoining the York and North Midland Railway, near Castleford, gave the following as its principal ingredients, viz.—

Carbonic acid	46·00
Lime	35·04
Magnesia	17·50
Red oxide of iron	0·90
Insoluble matter	0·50
Loss	0·06
	100·00

This limestone appears then to consist of 62·32 per cent. carbonate of lime, and 36·75 carbonate of magnesia, or approaching nearly to the constitution of dolomite, containing one atom carbonate of lime and one carbonate of magnesia.

From the above statement, it would appear that this species of limestone is not well calculated for agricultural purposes, except perhaps under peculiar circumstances, and applied in small quantities.

The upper magnesian limestone is in almost immediate succession to the lower one, and directly beneath the new red sandstone. It is found in considerable abundance at Knottingley and Brotherton, and in other localities in this county. Its specific gravity is about 2·64. It is of a grayish-brown colour, and much harder than the preceding variety.

According to analysis, the following are its principal ingredients, viz.—

Carbonic acid	42 35
Lime	51·61
Magnesia	a trace
Red oxide of iron	1·42
Insoluble matter	4·50
Loss	0·12
	100·00

As this limestone appears to contain about 93·96 per cent. carbonate of lime, it would seem to be tolerably well adapted for the purposes of agriculture, as the very small proportion of magnesia that it appears to contain can scarcely be supposed to exert much deleterious influence.

3. The *Oolitic Limestone* is the next in order to the magnesian, and is found in considerable abundance in the neighbourhood of Malton. It is of a yellowish-white colour, and appears to be composed of innumerable small round particles. The specific gravity is about 2·59.

According to analysis, its principal constituents are—

Carbonic acid	44·35
Lime	53·53
Red oxide of iron	0·69
Insoluble matter	1·26
Loss	0·17
	100·00

From the large proportion of carbonate of lime contained in this limestone, it appears to be well calculated for agricultural purposes, and is used to a considerable extent.

4. The *Chalk* formation occupies a considerable extent in the eastern part of the county, forming that peculiar feature in it known as the Wolds.

This substance scarcely requires any description. It is, as is well known, of a white colour, and easily scraped with a knife, and readily soils the fingers. Its specific gravity is about 2·55.

According to analysis, its chief ingredients are—

Carbonic acid	43·00
Lime	55·42
Insoluble matter	1·10
Loss	0·48
	100·00

This, like the preceding variety, appears to contain a large proportion of carbonate of lime, and consequently affords, by burning, a similarly large proportion of lime, and hence is particularly adapted for agricultural purposes, although it is said not to produce so strong a lime as the oolitic limestone.

On some Products of the Decomposition of Erythrin. By EDWARD SCHUNCK.

Erythrin is a white substance which forms the basis of the colouring matters produced from the *Roccella tinctoria*. It was discovered by Heeron, and afterwards examined by Kane. I have obtained very different results from the latter. The composition of erythrin is expressed by the formula $C_{20} H_{12} O_{10}$, or $C_{40} H_{24} O_{20}$. By treating with caustic alkalies it is decomposed into carbonic acid, which unites with the alkali and orcin, which remains dissolved. Now, if we subtract from $C_{40} H_{24} O_{20}$ two atoms of anhydrous orcin $C_{32} H_{12} O_4$, two atoms of carbonic acid $C_4 O_8$, and seven atoms of water $H_7 O_7$, there remains $C_4 H_5 O$, which is the composition of one atom of æther. It was therefore probable that during this decomposition alcohol would be given off, but no decided manifestations of alcohol could be discovered on decomposing with caustic potash. It is therefore probable that the elements of $C_4 H_5 O$ arrange themselves in a different way. On being boiled with water erythrin is converted into a soluble viscid substance, which after some time crystallizes; it has a very bitter taste. On being boiled with alcohol erythrin is converted partly into this bitter substance and partly into pseuderythrin. Now pseuderythrin, C_{22} H_{13} O_9, is the æther compound of lecanorin C_{18} H_8 O_8, so that it is probable that erythrin either contains lecanorin, as such, or that it easily gives rise to the formation of that substance; the bitter substance before mentioned is also decomposed by alkalies into carbonic acid and orcin. According to its constitution it ought also to give off alcohol or æther during this decomposition, but nothing of the kind could be discovered.

Note on the Solvent Power of Solutions of Acetates. By John Mercer, *Jun.*

In the course of some experiments on the crude acetate (pyrolignite) of lime, in which the author had occasion to bring the solution of this substance into contact with sulphate of lead (applied in the dry state), he was surprised to observe the solution experience a considerable increase in density, which proved to be owing to the solution of a large quantity of sulphate of lead. A portion of the liquid gave an abundant precipitate of chrome yellow, with a few drops of a solution of the bichromate of potash; but the original solution did not contain a trace of lead, nor did the sulphate employed in these experiments contain any soluble salt of lead.

The solution of the sulphate of lead is not affected by the impurities present in the crude acetate, as pure acetate of lime was found to possess an equal solvent power on the sulphate of lead.

As might have been expected after such a result, unequivocal evidences were obtained of the presence of lead in acetates prepared by double decomposition of the acetate of lead and a soluble sulphate, as acetates of soda, alumina and potash. The acetate of soda of commerce prepared in this manner, contained a notable quantity of lead, evidenced by bichromate of potash, sulphuric acid, and other reagents, though the acetate was in the state of large and perfectly transparent crystals.

A solution of acetate of soda prepared in the same way by the author, also contained lead, although the acetate of lead was not present in excess, for the addition of sulphate of soda to the liquid caused no precipitate. Moreover a solution of pure acetate of soda, prepared by carefully neutralizing acetic acid with caustic soda (both free from lead), was found to be capable of dissolving a large quantity of sulphate of lead, especially with the application of heat. All the acetates the author has had an opportunity of examining, namely, those of lime, soda, alumina, potash, ammonia, and magnesia, possess this solvent power.

The sulphate of lead is not the only lead compound insoluble in water which is capable of being dissolved by solutions of acetates, for the oxide, carbonate and subsulphate also partake of the property. The author has not yet been enabled to determine with certainty the exact state in which the lead exists in solution; the compound formed, however, would seem to be very stable, as the liquid may be boiled, diluted and evaporated until transparent crystals are obtained (where the acetate used is capable of crystallizing) without the separation of the lead.

It is perhaps worthy of observation, that the solutions of lead in acetates afford a precipitate of sulphate of lead with sulphuric acid, but not with sulphate of soda. Caustic soda also produces a precipitate.

The solvent power of acetates extends to many bodies insoluble in water besides the lead compounds above mentioned: for instance, a solution of neutral acetate of soda dissolves hydrated oxide of copper and lime in very large proportion; and alumina, protoxide of iron, and protoxide of tin, in small quantity; but hitherto the author has not had an opportunity of pursuing the investigation of this subject to the extent it deserves.

On Guano. By Robert Warington.

This was a notice intended particularly to draw attention to the importance of the estimation of the nitrogen in the analysis of guano as given to the agriculturist, as on the quantity of this element depended, in a great degree, the value of a given sample, whereas in general the per-centage of ammoniacal salts was only given. It appears, from Mr. Warington's experiments, and the use of guano in the production of the prussiate of potash, that the proportion of this element is very considerable.

On the Action of Nitric Acid on Naphtha. By Drs. Smith *and* Leigh.

This was an account of experiments which are still in progress, showing that by the action of nitric acid on naphtha, a variety of bodies isomeric with turpentine might be produced.

On the supposed Formation of Valerianic Acid from Indigo, and on the Acid which is formed by the Action of Hydrate of Potash upon Lycopodium.

By J. S. Muspratt, *Ph.D.*

The author presented an examination of the very remarkable series of metamorphoses to which indigo is subjected in the processes described by Gerhardt. It is contended that the valerianic acid produced in these experiments is not due to the indigo, but to foreign matters mixed up with it. A peculiar oleaginous matter had been obtained from lycopodium having a peculiarly acid character.

Experiments on the Formation or Secretion of Carbon by Animals, the Disappearance of Hydrogen and Oxygen, and the Generation of Animal Heat during the process. By Robert Rigg, *F.R.S.*

The experiments described in this paper were made with two young mice, confined in a wire trap; the one weighed 210 and the other 218 grains. They were fed with bread and water only; and at periods of half an hour, an hour, and sometimes for two hours, the animals when in the trap were placed several times in the day under a glass jar, atmospheric communication being cut off by mercury. Portions of the air within this jar were removed and examined for carbonic acid over mercury. One of the mice was under experiment nearly eight and the other nine weeks; during which time they were sometimes supplied with an abundant quantity, at other times a moderate, and at other times a very sparing quantity of food. With whatever quantity they were supplied, the carbon in the respired air exceeded that in the food; the former comprising during the whole period 2016, and the latter 1491 grains of carbon. One of the animals was killed when in its fattest condition, and when its weight was 276 grains, and the other when its weight was reduced, by being fed for several days with a very sparing quantity of food, to 169 grains. The animals were dried in their whole state, and average samples analysed with oxide of copper; the weight of carbon comprised in the former was 45·91 grains, and that in the latter 22·5 grains.

From these and similar results obtained by experiments made with other animals and birds, the author is led to conclude that animals secrete carbon; and on a recapitulation of the elements comprised in the animals, in the bread, and in the water, he is led to infer that hydrogen and oxygen undergo some process of natural chemistry, having this secreted carbon as a result: and by calculating for the specific heats of these bodies, he finds that these animals generate from three to six times the heat by the formation of the carbon they secrete, as by the formation of the carbonic acid they respire; and that this secretion of carbon, and consequently generation of heat, is influenced by the quality and quantity of food, exertion, and quiet or active habits of the animal.

On increasing the Intensity of the Oxyhydrogen Flame. By C. J. Jordan.

The author in this paper examines various processes of gaseous combustion, as the ordinary flame where heat is generated only at the coincident *surfaces* of oxygen and the combustible, and the flame of oxygen and hydrogen *previously mixed*, where at every point of the jet heat is generated. In this last case enlarged *bulk* of flame is advantageous, but not generally practicable with œconomy and convenience. Instead of augmenting the bulk, the author suggests concentration of the mixed gases by *pressure*, so as to accumulate more burning points within a given area, and thus raise the intensity of the flame, and supports this view by various facts and reasonings, chiefly derived from the effects which accompany gaseous combustion under reduced pressure or diluting aëriform admixtures.

To accomplish the production of the mixed oxyhydrogen flame, *under pressure*, the author proposes a strong vessel charged with compressed air, or some appropriate gas, and furnished with glass sight-holes (or composed of glass). Into this vessel the gases are to be forced under a somewhat greater pressure than that sustained by the vessel (ignited previously, or by an electric spark).

On Specific Heat. *By* J. P. Joule.

After examining the law of Dulong and Petit, that the specific heat of simple bodies is inversely proportional to their atomic weights, the author proceeded to detail the attempts made by Haycraft, De la Rive, and Marcet, to discover the specific heats of gases and liquids. The observations of Neumann and Regnault on the specific heats of simple and compound bodies were next examined. Mr. Joule then exhibited to the Section a table, in which the theoretical specific heats of a variety of bodies impartially selected were calculated on the hypothesis that the capacity for heat of a simple atom remains the same into whatever chemical combination it enters. On the whole, the coincidence between the theoretical and experimental results was such as would induce a belief that the law of Dulong and Petit, with regard to simple atoms, is capable of a greater degree of generalization than chemists have hitherto been inclined to admit.

TABLE.

Name of substance.	Formula adopted.	No. of atoms divided by equivalent.	Theoretical sp. heat.	Actual sp. heat.	Experimenter.
Water	H_2O	$\frac{3}{9}$	1000	1000	
Hydrogen	H_2	$\frac{2}{1}$	6000	3294	Delaroche and Berard.
Oxygen	O	$\frac{1}{8}$	375	236	do.
Iodine	I_2	$\frac{2}{126}$	48	54	V. Regnault.
Carbon	C	$\frac{1}{12}$	250	241	do.
Sulphur	S	$\frac{1}{16}$	188	188	Dulong and Petit.
Lead	Pb	$\frac{1}{103}$	29	29	do.
Zinc	Zn	$\frac{1}{33}$	91	93	do.
Copper	Cu	$\frac{1}{32}$	94	95	do.
Mercury	Hg	$\frac{1}{101}$	30	33	do.
Oxide of lead	PbO	$\frac{2}{111}$	54	51	V. Regnault.
Oxide of copper	CuO	$\frac{2}{40}$	150	142	do.
Magnesia	MgO	$\frac{2}{21}$	286	244	do.
Peroxide of iron	Fe_2O_3	$\frac{5}{78}$	192	167	do.
Sulphuret of copper	Cu_2S	$\frac{3}{80}$	113	121	do.
Sulphuret of lead	PbS	$\frac{2}{119}$	50	50	do.
Sulphuret of iron	FeS	$\frac{2}{43}$	140	136	do.
Chloride of lead	$PbCl_2$	$\frac{3}{139}$	65	66	do.
Chloride of copper	Cu_2Cl_2	$\frac{4}{100}$	120	138	do.
Iodide of lead	PbI_2	$\frac{3}{230}$	39	43	do.
Iodide of silver	Ag_2I_2	$\frac{4}{234}$	51	62	do.
Sulphate of potash	$KO\,SO_3$	$\frac{6}{88}$	204	190	do.
Carbonate of potash	$2KO\ CO_4$	$\frac{9}{139}$	194	216	do.
Chlorate of potash	$KO\ Cl_2O_5$	$\frac{9}{123}$	220	210	do.
Nitrate of potash	$KO\ N_2O_5$	$\frac{9}{102}$	265	238	do.
Sulphuric acid	$SO_3\,H_2O$	$\frac{7}{49}$	429	350	Dalton.

Account of Experiments on Heating by Steam. By W. West.

These experiments were instituted for the purpose of ascertaining if water heated by steam reached the true boiling temperature. In several experiments it was found that although the water was violently agitated, and steam escaped in abundance, that the thermometer indicated 190°, 205°, and 207°, and could not be raised to the true boiling-point. A false bottom being added to the receiving vessel pierced with numerous small holes, it was found easy, with even a smaller quantity of steam, to maintain the temperature at 212°.

On a peculiar Condition of Zinc, produced by a long-continued High Temperature. By Thomas Tilley, *Ph.D.*

Dr. Tilley presented a specimen of zinc, which had undergone a remarkable change in its arrangement, from being kept at a heat above that of fusion for a considerable time. This change was thought to bear some analogy to the alterations which sulphur and some other bodies are known to undergo at different temperatures. The condition of the zinc was singularly crystalline. The zinc in this state was found to have the same chemical condition as the ordinary zinc of commerce, and, although its oxides and salts have not been examined, it was found that, when distilled, the zinc was restored to its original texture. It was suggested, that many interesting examples of similar molecular changes in other metals might be detected by subjecting them to similar conditions to those in which this sample of zinc was placed.

Description of an Air-Duct to be used in Glass Furnaces for the Prevention of Smoke, with Models. By T. M. Greenhow.

The nuisance of smoke it is assumed must be prevented by the supply, under proper conditions, of additional quantities of oxygen gas to the burning matter, so as to render its combustion complete. Though this intention has been successfully carried out in steam-engine and other furnaces, no attempt has been successful to prevent the annoyance occasioned by glass furnaces. One of Mr. Greenhow's models represented the reverberatory furnace used in the manufacture of crown glass. In this kind of furnace the smoke and products of combustion escape through the openings in the sides which give the workmen access to the pots of glass, and are unprovided with flues. To provide the necessary supply of fresh air, Mr. Greenhow proposes a perpendicular air-duct (made of the same refractory clay of which the glass pots are constructed) rising through the middle of the fire, and supported by the stone arch on which the bars rest. This air-duct rises to the height of five feet within the furnace, is one foot in diameter, and distributes, through numerous apertures, any quantity of air that may be required for the completion of the combustion of the fuel; and from its situation in the centre of the furnace it must soon acquire and communicate a high degree of temperature to the air it transmits. Mr. Greenhow showed a second model of a steam-engine furnace with a horizontal air-duct placed anterior to the bridge, which it crowns and overlaps. At this situation heated air is distributed through small apertures, so as to mingle with the burning gases and ensure their more complete combustion.

On the Influence of Light on Chemical Compounds, and Electro-Chemical Action. By Robert Hunt.

After alluding to Sir John Herschel's experiments on the chloride of platinum, neutralized by lime water, from which a platinate of lime was precipitated by the influence of the solar rays, and to Dr. Draper's observations on the power which the solar beams had of imparting a property to chlorine of uniting with hydrogen under circumstances in which the same elements kept in the dark would not unite, Mr. Hunt called attention to some experiments in which still more remarkable results had been obtained. If a solution of mineral chameleon be made in the dark it does not undergo any change for many hours, whilst a similar solution will, if exposed to sunshine, precipitate heavily almost immediately. Sulphate of iron dissolved in common water, will, even in the dark, after some hours, give a precipitate of carbonate of iron; but if exposed to sunshine, this takes place instantly, and the weight of the precipitate, up to a certain point, is in both these cases a measure of the quantity of light to which the solutions have been exposed. A contrary effect to this has also been observed: if a solution of the bichromate of potash be mixed with one of sulphate of copper, and the mixture be set aside in the dark for twelve hours, the glass will become thickly coated with a chromate of copper, but a similar mixture exposed to the sunshine shows no such effect. Several solutions of the salts of silver were exposed to sunshine, whilst portions of the same solutions were kept in the dark. When small quantities of the sulphate of iron were added to these solutions, it was found that those which had been exposed to sunshine gave a precipitate immediately, whereas those which had been preserved in the dark did not precipitate for some time. It has also been noticed, that bichromate of potash, exposed to bright sunshine, precipitated chromate of silver of a much more beautiful colour than a similar solution which had been kept in darkness. A similar effect was seen in precipitating prussian blue by a solution of the ferro-prussiate of potash which had been exposed to the sun, the colour being infinitely more beautiful than that thrown down by a solution which had not been so exposed. A solution of the iodide of potassium was put into a glass tube, the lower end being closed by a diaphragm; this was put into another vessel containing a solution of nitrate of silver, and a platina wire passed from one solution into the other. Such an arrangement being placed in the dark, a beautiful crystallization of metallic silver took place about the wire, but if placed in the sunshine this crystallization was entirely prevented. The attention of chemists was called to these results, which certainly show that the agency of the chemical rays must in future form an important subject of investigation, particularly when any delicate analysis is desirable. These, and similar experiments, belong to an important branch of chemical science, for which the epithet of Actino-Chemistry has been proposed by Sir John Herschel.

On the Ferrotype, and the Property of Sulphate of Iron in developing Photographic Images. By ROBERT HUNT.

The new photographic process, to which the above name is given, consists essentially in the development of a dormant photographic image, formed on a paper prepared with succinic acid and nitrate of silver, by the deoxidizing power of sulphate of iron. Numerous failures have been communicated to the author, which appeared to arise from the varying rates of solubility possessed by succinic acid obtained from different manufacturers. It was now recommended, that five grains of succinic acid should be put into a fluid ounce of distilled water, and allowed entirely to dissolve; the salt and gum is then to be added to this solution, and the author believes that, with care, the effects will be certain. Recent researches have, however, proved that this property of the sulphate of iron may be made available on *any photographic paper*. On paper merely washed with the nitrate of silver, good camera pictures have been thus obtained in a few minutes, and on papers prepared with the chloride of sodium, bromide of potassium, and particularly the iodide of potassium, camera views are procured in less than a minute. Mr. Hunt exhibited a great number of specimens procured on the above and many other salts of silver—the most beautiful being on papers covered with the acetate, the benzoate, the citrate, and other organic salts of silver. These drawings were all fixed by washing with moderately strong ammonia.

On the Electrolysotype; a new Photographic Process.
By THOMAS WOODS, *M.D.*

[The following are extracts from this paper].—While investigating the property that sugar possesses in some cases of preventing precipitation, I noticed, that when syrup of ioduret of iron was mixed with solution of nitrate of silver in certain proportions, the precipitate was very quickly darkened when exposed to the light, and I thought that if properly used it might be employed with advantage as a photographic agent.

Let well-glazed paper be steeped in water to which hydrochloric acid has been added, in the proportion of two drops to three ounces; when well-soaked, let it be washed over with the following mixture:—take of syrup of ioduret of iron half a drachm, of water two and a half drachms, and of iodine one or two drops; mix. When it has remained wet for a little time let it be dried lightly with bibulous paper, and brushed over again with the same mixture; let it be again dried with the bibulous paper, and being removed to a dark room, let it be washed evenly over with a solution of nitrate of silver—twelve grains to the ounce of water. The iodide of silver which is formed should be disturbed as little as possible by the camel's hair pencil with which the nitrate of silver is laid on. The paper is now ready for use; the sooner it is used the better, as when the ingredients are not rightly proportioned it is liable to be spoiled by keeping. I have obtained pictures with it when prepared for twelve hours, but I have not tried it after having kept it for a longer period. The time I generally allow the paper to be exposed, when used in the camera, varies from one second to half a minute in clear weather. With a bright light the picture obtained is of a rich brown colour; with a faint light, or a bright light for a short time continued, it is black. If the paper be left exposed for too long a time the minute parts of the picture are confused. For taking portraits in the shade out of doors on a clear day, fifteen seconds will be the time for sitting. When the paper is removed from the camera, no picture is visible; however, when left in the dark for some time, the duration of which will vary with the time it was exposed to light, it gradually developes itself, until it arrives at a state of perfection, which is not, I think, attained by photographs produced by any other process. The action set up by the light is continued in the dark, an electrolysis taking place by which the picture is brought out; and for this reason I have ventured to name the process, for want of a better word, the Electrolysotype. Sir J. Herschel observed long ago this fact of the action of light continuing after its influence is apparently removed, especially in the salts of iron; but I do not know of any process being employed for photographic purposes which depends on this action for its development except my own. The pictures are fixed by first steeping them well in water, then in a solution of bromide of potassium, twenty grains to the ounce; and then again in water, to remove the bromide from the paper.

If the acid solution is too strong, it impairs the sensibility of the paper. If the nitrate of silver solution is too strong, the paper blackens in the dark after having been for some time kept; if too weak, it remains yellow, even though exposed to the light. If the ioduret of iron is in too great quantity, the picture becomes dotted over with black spots in the dark, which are rapidly bleached by the light.

Of the specimens exhibited, No. 1 was a paper darkened by the moonlight in fifteen minutes.

On Photography. *By* Professor Grove.

Mr. Grove communicated experiments he had made with some success in obtaining a paper capable of giving positive photographs by one process, and avoiding the necessity of transfer, by which the imperfections of the paper are shown. As light favours many chemical actions, Mr. Grove thought that a paper darkened by the sun (which darkening is supposed to result from the precipitation of silver), might be bleached by using a solvent which would not attack the silver in the dark, but would do so in the light. Among other acids tried, nitric acid succeeded best. Thus a darkened calotype paper is re-iodized by iodide of potassium, and then drawn over dilute nitric acid, one part acid to two and a half water; when so prepared it is rapidly bleached by exposure to light, and perfectly fixed by washing in water and dipping in hyposulphite of soda, or bromide of potassium. If the acid be strong, say one-half water, the paper will be bleached in ten seconds by the sun, but then it partially bleaches in the dark.

Mr. Grove showed some lithographs copied by this process; but stated, that in the very few trials he had made with the camera the images had not been clear; that he had then tried the following method:—Let an ordinary calotype image or portrait be taken in a camera and developed by gallic acid, then drawn over iodide of potassium and nitric acid, and exposed to full sunshine; while bleaching the dark parts, the light is re-darkening the newly precipitated iodide in the lighter portions, and thus the negative picture is converted into a positive one. It is, however, faint, and gallic acid will not develope it; possibly some other solutions, such as those of iron, may; but Mr. Grove had not had time to try them. He believed from what he had observed, that a great many cases would be found in which a negative picture might be changed to a positive one, and that in some of these very good positive effects would probably be obtained.

Some impressions, sent by Dr. Hamel, from Daguerréotype plates, which had been etched in Paris by the agency of an acid, were exhibited.

Mr. Matteucci communicated to the Section the results of some experiments made by him with the view of establishing the relation which the amount of mechanical work realized by the consumption of a given quantity of zinc acting as a voltaic combination upon the limbs of a frog, bears to the amount of work realized by the same quantity of zinc employed as a generator of mechanical force in other inorganic applications. A given weight is attached to the feet of a recently-prepared frog, this and the weight are suspended from a platina wire by the portion of the spine, and another platina wire passes through the lower part of the sciatic nerves; these wires are connected with the terminals of a voltaic battery, a voltameter being interposed in the circuit.

By making and breaking voltaic contact, the muscles contract, the weight is raised.

By connecting a contact breaker with the moving limbs, these are enabled to interrupt and complete the voltaic circuit by their own contractions, and a register attached shows the number of interruptions in a given time.

An index is also attached to the weight, which bearing upon a revolving sooted disc registers the distance and velocity of the motion of the weight. Thus we get the elements of time, space, and weight. From experiments performed in this manner M. Matteucci finds that 3 milligrams of zinc consumed in twenty-four hours give $5^{\mathrm{k}}\cdot 5419$ of weight raised through a given space, while the same quantity of zinc, or its equivalent of carbon, employed to generate motion by combination in a steam-engine gives $0^{\mathrm{k}}\cdot 834$; or employed to work an electro-magnetic machine, gives $0^{\mathrm{k}}\cdot 96$.

Several reductions must be made to eliminate extraneous actions which do not contribute to the resulting effect; thus a voltaic battery of sufficient intensity to decompose water must be much more powerful than is requisite to convulse the limbs of the frog. The conducting power of the pelvic muscles, which if cut off weaken too much the general effect, must also be deducted, as well as the antagonist force of the extensor muscles. The necessity for all these reductions makes the problem a very complex one. M. Matteucci believes, however, that he has done sufficient to establish the general result that a far greater amount of work can be realized from the consumption of a given quantity of zinc acting on the limbs of a recently-killed animal, than when the same quantity is employed to work an inorganic machine[*].

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[*] On the 30th September, M. Matteucci showed at his lodgings to several Members of the Association, some of the most important of the experiments detailed in his recently published work on Electro-Physiology.

1st. *The Muscular Current.*—If the sciatic nerve of the limb of a prepared frog be made to touch at the same time the external and internal muscle of a living or recently-killed animal, the limb is convulsed. By forming a series of external and internal muscles, for instance, severing the lower halves of the thighs of a certain number of frogs, and inserting the knee of the one into the central muscle of the second, and so on, a voltaic pile will be formed, six or eight elements of which M. Matteucci showed were capable of deflecting a galvanometer, or producing convulsions in an electroscopic frog.

The direction of the voltaic current is from the interior to the exterior of the muscle, and the current is more feeble in proportion as the animal is higher in the scale of creation.

2nd. M. Matteucci explained *the specific voltaic current* (*courant propre*) *of the frog* as being a current which is detected only in the frog, and which is directed from the feet to the head of the animal.

3rd. M. Matteucci showed an experiment by which it appeared that a muscle whilst undergoing contraction is capable of exciting the nerve of another recently-killed animal, so as to produce muscular contraction in the latter. He laid the sciatic nerve of one leg of a prepared frog on the thigh of another, and by touching the nerve of the latter with an arc of zinc and copper this was convulsed, and at the same time the first leg, the nerve of which formed no part of the voltaic circuit, was simultaneously convulsed, the legs all moving as though they formed part of the same animal.

4th. M. Matteucci explained some joint researches of himself and M. Longet, by

Prof. Grove communicated a notice by M. Gassiot, of a repetition of his experiment on the production of electricity without contact.

On a Method of Electrotype, by which the Deposition on Minute Objects is easily accomplished. By L. L. B. Ibbetson, *F.G.S.*

From the difficulties which arose from the application of plumbago, in the ordinary manner, a portion of the plumbago was united with a solution of phosphorus in naphtha, and the article to be electrotyped immersed in it. It thus became covered with a coating, on which the metal was deposited in a beautiful and uniform manner. Some specimens of cactuses thus covered with metal were exhibited.

On the Alternate Spheres of Attraction and Repulsion, noticed by Newton, Boscovich *and others; and on Chemical Affinity. By* Thomas Exley, *A.M.*

These phænomena have not been explained by means of fixed general principles, but may be explained by the two principles of a new theory, which are these :—

1st. That every atom of matter consists of an indefinitely great sphere of force, varying inversely as the square of the distance from the centre: in a very small concentric sphere the direction is from the centre, and is called repulsion; at all other distances it acts towards the centre, and is called attraction.

2nd. Atoms are of different sorts when their absolute forces, or their spheres of repulsion, are unequal.

These simple principles, duly carried out and rightly applied, are sufficient to explain all the phænomena of the universe, a proper number of sorts and quantity of each sort being admitted.

From phænomena it appears that there are four distinct classes of atoms. Class 1st are denominated tenacious atoms, because they adhere with great force or tenacity: there are fifty-six sorts of tenacious atoms, as oxygen, hydrogen, carbon, &c. Class 2nd embraces the electric atoms, having a much less force, but greater sphere of repulsion than tenacious atoms; of these there seems to be but one sort. Class 3rd are æthereal atoms, constituting æthereal fluids; of these there appear to be several sorts; their absolute forces are very much less than even those of electric atoms, and their spheres of repulsion much greater. Class 4th, not concerned in this paper, comprises atoms which have an exceedingly small absolute force, and also an exceedingly small sphere of repulsion; its atoms may be called microgenal atoms.

Newton, Boscovich and others, conclude from observation, that near the centres of atoms there are several alternations of attraction and repulsion; Dr. Priestley says that the phænomena of nature cannot be explained without them; hence the true theory of physics ought to show that such alternations exist. The author proceeds to prove that they result from his principles.

In the earth's atmosphere we recognize very distinctly the tenacious, the electric, and the æthereal atoms; the tenacious atoms extend to about the altitude of forty-five miles, as is known by the refraction and reflexion of light; the electric atoms must extend much higher, and the æthereal class to a very great altitude, perhaps some hundreds of miles. The upper parts pressing on the lower give a considerable density to the three classes near the earth's surface. The space occupied by a given portion of tenacious atoms is diminished by pressure, and increased by an elevated temperature, that is, by an accession of æthereal matter.

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which it was proved that a different galvanic result is produced upon the nerves of an animal at a certain period after death, if the current acts upon the nerve of motion, or centrifugal nerve only, from that which ensues if the mixed nerve, centrifugal and centripetal, be subjected to the current; in the former case the muscular contraction takes place at the interruption of the direct current, or that which passes from the nervous centre to the extremities, and the commencement of the inverse current, or that which passes in the opposite direction; while in the latter case the reverse effect obtains, the contraction taking place at the commencement of the direct and at the interruption of the inverse current.

Mr. Exley showed by reasoning and the aid of diagrams, that there are several distinct collections of æthereal atoms, and one of electric atoms in concentric spheres about every tenacious atom: these he named and stated as follows:—1st, the sphere of repulsion of the tenacious atom; 2nd, the attached atmosphere; 3rd, the neutral shell; 4th, the electric surface; 5th, the electric shell; 6th, the diametrical shell; and 7th, the secondary attached atmosphere; and these produce the following alternations of force, viz.—

1st. The sphere of repulsion of the tenacious atom unaltered.

2nd. The concave side of the attached atmosphere accelerating the motion of atoms which have just passed, and thus having the effect of attraction.

3rd. The convex side of that surface resisting the passage of atoms, and thus having the effect of repulsion.

4th. The neutral shell.

5th. The concave side of the electric surface attracting.

6th. The convex side of the same repelling.

7th. The electric shell attractive.

8th. The diametrical shell attractive with increasing force from its concave to its convex side.

9th. The concave side of the secondary attached atmosphere attracting.

10th. The convex side of the same repelling.

It is to be understood that these are distinct from the æthereal matter present in consequence of pressure, which is everywhere uniform. Also there will be a different set of the last three for each sort of æthereal atoms which have a different sphere of repulsion: the others will remain the same.

These deductions prove, independently of experiment, that many alternations of attraction and repulsion exist as a legitimate inference from the principles above stated, and they correspond with what Newton, Boscovich and others have stated concerning them, which establishes this part of the subject. Hence the new theory possesses all the advantages, both of that of Newton and that of Boscovich, with innumerable other advantages.

For explaining chemical affinity the author deduces from his theory the following laws:—

Law I. Two tenacious atoms unite without the mediation of a third, and the volume is the same as that of the two constituents when the electric fluid collects between them, but the volume is reduced exactly one-half when the electric fluid collects on the outside.

Law II. Two atoms combine by the mediation of a third, and the volume is the same as that of the two extremes when the electric fluid collects along with the intermediate atom between them; but when it collects on the exterior, the volume is reduced to exactly one volume, that is, one-half the extremes.

Law III. In all cases where chemical union is effected, it is one atom with one, or two with one.

These laws he illustrated by selected examples.

In the original paper, the above statements, with other particulars, were illustrated by diagrams, and the following symbols represent the arrangements of combined atoms. The three dots in the parenthesis are to denote the interposition of electric fluid.

Law I.—*Two volumes.*

Muriatic acid	Cl(.·.)H
Carbonic oxide	O(.·.)C
Nitric oxide	O(.·.)N
Hydrobromic acid	Br(.·.)H.
&c.	

One volume.

Cyanogen	(CN)
E. Davy's carburetted hydrogen	(CH)
Chloruret of sulphur	(Cl,S)
Chloride of mercury	(Cl,Hg).
&c.	

Law II.—*Two volumes, viz. that of the extremes.*

Carbonic acid	$O(C)O$
Water vapour	$H(O)H$
Methylene or methyle	$H(C)H$
Deutoxide of chlorine	$O(Cl)O$
Alcohol	$H_2C(H_2O)CH_2$
Æther	$H_4C_2(H_2O)C_2H_4$
Œnanthic æther	$H_4C_2(H_{26}C_{14}O_2H_2O)C_2H_4$.
&c.	

One volume.

Nitrous acid	(NO_2)
Olefiant gas	(CH_2)
Benzin	$(CH)_2CH=(C_3H_3)$
Olein	$(CH_2)_2CH_2=(C_3H_6)$[*].
&c.	

On the Constitution of Matter. By Sir G. Gibbes, *M.D.*

The principal point in the paper was the attempt to establish the formation of heat by the union of the two fluids of electricity.

On the Alteration that takes place in Iron by being exposed to long-continued Vibration. By W. Lucas.

At the last meeting of the British Association, held at Cork, this subject was again brought forward, and certain specimens of iron exhibited, in order to show the effects produced upon the iron by being exposed to a certain degree of concussion or vibration during the process of swaging, and again restored to its original state by being annealed, in accordance with the results detailed by Mr. Nasmyth, at Manchester, in 1842; in addition to these were also exhibited specimens of portions of the same iron that had been exposed to the concussion of a large tilt hammer, working at the rate of about 350 strokes per minute, which occasioned the bars of iron to break short off at the point of bearing in the course of twenty-four hours; there was also shown a portion of one of the hammer shafts, the texture of which had evidently been altered, probably by the long-continued and repeated concussions to which it had been exposed; for instead of breaking with the splintery fracture common to wood, it broke with a peculiar short fracture, and this, Mr. Lucas is informed, is a very common occurrence. In continuance of these experiments upon the effects of concussion or vibration, Mr. Lucas laid before the Section the results of some further experiments.

The specimens now exhibited were portions of the iron already alluded to which had been fastened upon the top of a tilt hammer working at the speed previously mentioned, and allowed to remain in that position for a period of from six to seven months; it may be proper here to remark, that they were so placed that no tensile force was exerted, but only a vibratory action, and that was communicated to them through the body of the hammer itself; and a mere inspection of these specimens will convince almost any individual that an alteration has been produced in the molecular constitution of the metal in comparison with the original specimens, as in the specimens Nos. 1 and 3 the original fibrous texture has in a great measure disappeared and been replaced by a crystalline one, whilst in No. 2 (which has been previously swaged) it has entirely disappeared, and the iron has become perfectly crystalline; and it is probable that by further exposure to this action the crystals may increase in size, and assume a more definite form.

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[*] These elements also unite in two volumes, as in Dr. Faraday's oil-gas.

GEOLOGY AND PHYSICAL GEOGRAPHY.

On a newly-discovered Species of Unio, from the Wealden Strata of the Isle of Wight. By G. A. Mantell, *LL.D, F.R.S.*

This species, believed by the author to be newly discovered, and named by him *U. valdensis*, was obtained from the Wealden strata near Brook, associated with bones of the Iguanodon and other reptiles, on the southern coast of the Isle of Wight; several specimens were found, all of them more nearly resembling the massive and pearly shells of the same genus occurring in the Ohio and Mississippi rivers than any hitherto observed in a fossil state; and this resemblance is so close that it is considered an additional corroboration of an opinion formerly expressed by the author, namely, that a large proportion of the Wealden deposits must be considered as entirely of fluviatile origin, and not as the accumulated debris of an estuary.

Dr. Mantell states that the shells of the genus *Unio*, hitherto known as Wealden, are few and of small size, the largest not being more than two inches in length, and delicate, while the species now described is from five to six inches long, and so thick and massive, that a pair of valves cleared from all extraneous matter weighs above eleven ounces. These shells are in a fine state of preservation, the ligament, and even a portion of the original colour remaining. The author added a full description, referring to finished drawings of the shells.

On Mining Records, and the Means by which their Preservation may be best ensured. By Professor Ansted, *M.A., F.R.S.*

The author first alluded to a previous communication on this subject made by Mr. Sopwith in 1838, and the subsequent establishment of the Mining Records Office, but stated that such means were insufficient, and that regulations required to be made and enforced by the authority of parliament. The object of the paper was, first, to direct attention to the extent to which the mining interests of England would be promoted by the establishment of a system of mining records; secondly, to show that parliamentary interference is imperatively called for, if any satisfactory result is to be attained; and thirdly, that the efforts of the British Association would probably be successful if proper means are taken, whether by suggestions to government, or by pressing on public attention the importance of the subject, and inducing the government to set on foot the necessary inquiries.

In reference to the first object, the author adverted to the benefits to be expected from the possession of a system of mining records, both with reference to the miner directly, enabling him to avoid danger and certain disappointment, and still more in the application of pure geology to mining. This latter is indeed chiefly difficult and doubtful, because the observations recorded are, compared with what they should be, so few, imperfect and unsatisfactory, since the phænomena relative to the appearance, direction and condition of mineral veins have been till lately almost entirely neglected in England.

With regard to the extent to which these records are required, they are simply the accounts of observations which everyone entrusted with the management of mining property ought to be familiar with, in order that the proprietor may know how much mineral produce is abstracted from the bowels of the earth, and the position of that which is left. They are therefore necessarily made, and only require to be recorded.

The author then mentioned the different ways in which such records would be useful; among which he particularized the drainage of mines, and the being able to avoid occasional dishonesty, effected by wilfully causing the drainage of the mines of one proprietor to flow into those of another at a greater depth. Other kinds of dishonesty, more direct than this, are also sometimes perpetrated, owing to the impossibility of watching the under-ground progress of a miner suspected of dishonesty, at least without the expenditure of so much time and money as to render it unadvisable.

But besides these acts of dishonesty, many serious encroachments of property have been made, and expensive litigation has arisen, from the ignorance of the persons employed in under-ground works; and with respect to these, and also to future workings, we may form an idea of the use of records by the extent to which they are now needed. Numerous accidents have happened from the want of accurate plans of extinct workings; and yet not less than thirteen mines have been relinquished within the last half-century, all of them in the immediate neighbourhood of Newcastle, and of none of these are such records remaining as to render it possible to discover the exact direction of the old workings. It was urged that there is not only this danger arising from the old workings, but that very often valuable property is lost, when by an improvement in mining processes it might be desirable to re-open some of these deserted mines. The registration of all circumstances attending the relinquishment of mines, will, however, never be undertaken by the owners of the property, who can hardly be expected to put themselves to expense for what they of course suppose to be valueless; and it is only by some legislative enactment that the result, so desirable and so necessary, can be attained.

The author then described the regulations enforced in Saxony with regard to this subject, and proceeded to show that the indifference and mutual jealousy, as well as the ignorance, of small mining proprietors, rendered it certain that in most cases nothing short of an act of parliament would be effectual, and that any system that might be devised, must be as a whole imperfect and unsatisfactory, unless compulsory upon all. In conclusion, Professor Ansted dwelt upon the advantage possessed by the British Association, and the weight of the recommendations made at its instance; and stated, that as in this way scientific men in England can most powerfully assist the government, it was a duty incumbent on them to make some effort with regard to this subject, which was of greater practical importance than any that had come before the notice of the Geological Section.

On the Tertiary and Cretaceous Formations of the Isle of Wight. By Prof. E. Forbes, *F.L.S., and* L. L. Boscawen Ibbetson, *F.G.S.* Accompanied by Models of part of the Coast of the Back of the Isle of Wight.

The models to which this paper related were constructed by Capt. Ibbetson, from trigonometrical survey, in order to illustrate the sections of the cretaceous and tertiary systems on the S.E. coast of the Isle of Wight. They are three; the first exhibiting the section of the lower greensand between Blackgang chine and Atherfield point, in which that formation is grouped into three divisions, depending on mineral character and the consequent modifications of the distribution of their organic contents. The details of these had been previously laid before the Geological Society, in a paper written with a view to inquire into the Neocomian question, the result of which was to bear testimony to the correctness and prior claim of the important researches of Dr. Fitton. On the first of the models are also displayed the sections of the gault and of the upper greensand at St. Catherine's Down. The second model exhibited the corresponding section of the lower greensand, gault, and upper greensand between Luccomb and Sandown. In this section the beds correspond throughout the lower and middle divisions of the lower greensand, but the uppermost exhibits towards its base zones of Gryphææ and Terebratulæ, which are absent at the former locality. Generally speaking, the upper portion of the lower greensand in this section is much more fossiliferous. The third of the models displays the whole of the strata of the cretaceous system, as seen in the Isle of Wight, between Sandown and Whitecliff bay, and the whole of the eocene tertiary at the last-named locality. The strata of the lower greensand in this section correspond to those at Atherfield, but are much thinner, especially the clays of the lower part, and with the exception of the *Perna mulleti* bed, much less fossiliferous. The gault is free from fossils. The upper greensand corresponds nearly with the section at St. Catherine's Down, presenting successively sands and clays, under the names of chloritic marl, siliceous bands, firestone and freestone, malm and rag, the malm in a 3-feet bed, highly fossiliferous, surmounted by 26 feet of malm and rag passing into chalk marl. The thickness of the gault in this section is about 50 feet, of the upper greensand 100 feet, of the chalk marl and hard chalk 200 feet, and of the chalk with flints, the uppermost portion of which is absent, 200 feet. Resting on the denuded surface of the chalk, and heaved up almost perpendicularly, at Whitecliff bay are seen the strata of the London clay, consisting, at first, of a succession of marine clays and sands, succeeded by clays and sands apparently deposited in brackish water, which are divided from the marine by a bed of freshwater origin, and which are succeeded by a series of freshwater beds of various mineral characters, in the midst of which a thin stratum of marine or brackish origin suddenly appears. The measurements of all the strata, both tertiary and cretaceous, and tables of their fossil contents, were laid before the meeting.

Reviewing the strata deposited from the cessation of the Wealden to the prevalence of a freshwater eocene formation in this locality, the authors laid stress on the following facts in the local history of organised nature during that long period:—1. That the seas in which the lower greensand was deposited, and which occupied the area described, in consequence of the sudden subsidence of the great Wealden lakes, presented from the very commencement a fauna truly marine, and most of the members of which began their existence with the commencement of the cretaceous æra in England. Almost all the animals which appeared were such as were new to the oceanic fauna; and among them were many forms representative of other species which had existed in the oolitic ocean. 2. That this fauna continued, though apparently diminishing in consequence of extinction of species from physical causes, until the commencement of the deposition of the gault, when a new series of animals commenced, among which a few species which had previously existed lived on, but the greater part of which were either representative or peculiar forms. The same system of animal life appears to have continued throughout the remainder of the cretaceous æra in this locality, although great differences in the distribution of species and many species local in time occur, depending on the very great change in the mineral conditions of the sea-bottom during this epoch. The chalks proper present especially many peculiar species, but these appear rather to owe their presence to the zone of depth in which they lived, than to being members of a new zoological representation in time. The authors called attention to the assemblage of minute corals, sea-urchins, Terebratulæ, and *Spondylus spinosus*, in that part of the Culver section at which is seen the junction of the chalk with flints and the hard chalk, as especially indicative of a very deep sea, and as corresponding to the characters which mark a very deep sea fauna at the present period. 3. That in the tertiary formations which succeed there is an entirely new fauna, distinct as to every species in this locality, though elsewhere linked with the cretaceous strata last alluded to by the presence of that remarkable mollusk, the *Terebratula caput-serpentis*, which lives even at the present day. Of this fauna, which did not appear until after a considerable bed of mottled clays, without traces of animal life, had been deposited, the commencement is similar to the commencement of the faunas of the two cretaceous periods already described; viz. by a series of clays containing numerous peculiar Mya-form shells, Pectunculi, Ostreæ, and their associates. The earliest fossiliferous bed at Whitecliff bay is a most remarkable one, consisting of a thin stratum almost entirely composed of a species of shell-bearing annelid, the Ditrupa (*Dentalium planum* of Min. Conch.), which appears to have lived but a short specific life in time, and to have suddenly disappeared. In the midst of these beds, strata charged with myriads of foraminifera, probably indicating some change in the sea's depth, appear and cease. The sudden conversion of the sea into a freshwater lake, indicated by a stratum of paludina clay, its return into a brackish state, and the consequent re-appearance of certain marine animals, its re-conversion into a freshwater lake thronged with myriads of fluviatile mollusca, and the almost momentary influx of salt water during that period, which lasted only long enough for a race of oysters to live and die away,—all render the tertiary strata in this locality highly interesting.

From the great zoological break between the eocene and the chalk, the authors conclude that a third or uppermost cretaceous formation, characterised by a fauna which would link the middle term of the system with the lowest term of the tertiary, has disappeared in this locality; whilst they regard the portion of the cretaceous system there present as composed of two divisions, equivalent in time; the older consisting of the lower greensand, and the upper, or later, forming one system, composed of the gault, upper greensand, and chalks.

The zoological epochs exhibited in the section, commented on and modelled, are therefore three, viz.—1, the lower cretaceous system; 2, the middle cretaceous system; and, 3, the lower or eocene tertiary system.

Critical Remarks on certain Passages in Dr. Buckland's *Bridgewater Treatise. By the* Very Rev. the DEAN OF YORK.

On the Excavation of the Rocky Channels of Rivers by the Recession of their Cataracts. By G. W. Featherstonhaugh, *F.R.S., F.G.S.*

The author of this communication (now Her Majesty's Consul at Havre de Grace), in travelling through North America, had noticed that at some points of the course of all the great rivers there was either a cataract, or evidence of the former existence of one, in rapids now obstructing navigation; and on comparing the quantity of water in the rivers now, with certain marks which appeared to indicate the quantity which formerly flowed in their channels, he came to the conclusion that the volume of water was formerly much greater than at present, and that such a state of things was necessary for the excavation of their rocky channels, which he considers to have been effected by the recession of their cataracts.

In the case of the St. Lawrence and its tributaries, evidence to this effect is said by Mr. Featherstonhaugh to be very complete. The isthmus separating lakes Huron and Erie is a lacustrine deposit, containing everywhere decayed freshwater shells, and the land which separates the Wisconsin (a tributary of the Mississippi) from Upper Fox River, a tributary of Green Bay, which is an elbow of Lake Huron, is so little above the general level of the country, that it is now passed over in boats in the flood season. It is therefore inferred that when these alluvial plains and lacustrine deposits were under water, there was free freshwater communication between the St. Lawrence and the Mississippi.

The author then proceeded to quote the Mississippi as another example illustrating his views; and stated that that river for several hundred miles of its course south of the Falls of St. Anthony, runs through a valley, from one to two and a half miles in breadth, bounded by escarpments from 200 to 450 feet high. On looking down upon this valley from the heights, it appears as if the whole had been originally the bed of the river.

It is however evident that the river channel could not have been eroded to its present extent by the water that now runs through it; and Mr. Featherstonhaugh therefore suggests, that the volume of the Mississippi, which accomplished the work, was much greater formerly than at present.

The author then illustrates two methods by which he considers that the rocky channels of rivers may have been excavated by the recession of their cataracts; one he denominates the *molar*, or grinding, and the other the *subtracting*, or undermining process. In describing the effects produced by the first, he referred to a cataract near 600 feet in height, called Oonaykay-amāh, or the white-water, situated in the Cherokee country, on the east flank of the Alleghanies, and not hitherto described by travellers. The rock here is compact gneiss, and it appears that the rush of water eddying in the accidental hollows of the surface excavates cavities or pot-holes, some of them of very large size, one of which measured four feet in diameter and six feet deep. In many instances the rock was observed to be almost filled with these hollows, which at last coalesce, and become larger, several uniting in one, until at the season of floods considerable masses are detached, and precipitated below by the cataract. Immense masses of rock perforated and detached in this way were found at the bottom.

It appeared to the author, that the gorge into which this cataract fell (a gorge several miles long, and near 600 feet deep) had been ground out of the solid rock in this way; and it was considered to add to the interest of the case that at one spot there were indications in a circular ledge of gneiss adjacent to the cataract, and worn bare for a great distance from the top, that it had at one time plunged over this semicircular ledge, at a period when the volume of the water was immensely greater than it is at present.

Of the other process, that of undermining, the cataract of Niagara was adduced as an instance. The Niagara river flows upon a bed of compact limestone, overlying a friable shale upwards of seventy feet thick, and the sheet of water having fallen over the edge of limestone, forms a sort of screen before the shale; while behind this screen, the constant moisture, the violent concussion, and the strong current of air loosen and disintegrate the shale, which falls down and is washed away, leaving the limestone without support. This process continues incessantly; and the author, in a paper published in 1831, showed that the gorge beyond the fall had been cut from the heights of Queenstown to the point where it now is (a distance of seven miles), by a recession, depending upon this alternation of hard and soft strata. The excavation, however, goes on more slowly now, partly from the much wider extent of the falls weakening the force of the water at any one point, and partly, the author imagines, from the volume of water having diminished.

In conclusion, the author thinks it possible that even in our own island we are not precluded from supposing that the same causes may have excavated river channels, since it may be considered that England was at one time a portion of a great continent.

On the Midland Coal Formations of England. *By* ELIAS HALL.

An Account of that Portion of the Ordnance Geological Map of England now completely coloured, and Notes concerning a Section through the Silurian Rocks in the vicinity of Builth. *By* Sir H. T. DE LA BECHE, *F.R.S., &c.*

The author gave an account of the method adopted in pursuing the geological survey of England, and the nature and degree of accuracy of the maps and accompanying sections. He then stated that the vicinity of Builth is one of much geological interest, as showing the connexion between the Silurian rocks at Ludlow, Wenlock, and other localities on the N.E., with the same deposits in Brecon, Carmarthen, &c., and as affording considerable instruction relative to the intermixture of sedimentary and igneous rock at this early period. The section described was part of one now making by the Geological Survey between the old red sandstone of the Black Mountains in Brecon and the sea north of Aberystwith. Sir H. De la Beche then compared this development of the Silurian rocks with that in Siluria, and observed, that although there is but a trace of the Wenlock and Aymestry limestones near Builth, still there is a general resemblance to the sequence described by Mr. Murchison at Malvern, Woolhope, &c. It is at the base of the Wenlock shales that the greatest modification is found; instead of the Caradoc limestone and sandstone are the shales and slates with *Asaphus Buchii*, and beneath these a mixture of conglomerates, sandstones, &c., with similar fossils; so that either the sandstones representing the Caradoc are included in the Llandeilo flags, and one appellation must be applied to both, or the Caradoc sandstone must be supposed to have thinned off, so as not to occur in the Builth and western sections.

On certain Silurian Districts of Ireland. *By* RICHARD GRIFFITH, *F.G.S.*

In this communication, Mr. Griffith first noticed the occurrence of Silurian fossils in two extensive districts in Ireland, which have been examined by him during the period which has intervened since the Meeting at Cork. One of those districts is situated on the west, and the other on the east coast. That on the west was stated to occupy a considerable portion of the counties of Mayo and Galway, to the north and south of the remarkable estuary called Killery Harbour.

This district is bounded on the north by the mountain range of Croagh Patrick in Mayo (which is chiefly composed of mica slate), and on the south by the primary mountain group, called the Twelve Pins of Connemara, in the county of Galway.

Mr. Griffith exhibited a detailed section of the strata extending from south to north from Galway Bay, across the western portion of the group of the Twelve Pins, and thence by Killery Harbour towards Croagh Patrick. The district immediately to the north of Galway Bay consists of sienitic granite, and occupies a tract of country ten miles in breadth. It is succeeded on the north by a metamorphic district, (consisting of imperfectly stratified rocks, presenting the characters of imperfect gneiss, hornblende slate, and semi-porphyry, having sometimes a siliceous, and sometimes a hornblendic base,) which occupies a stripe of country varying from two to six miles in breadth. Beyond is the central group of the Twelve Pins, which is composed of alternations of mica-slate, white quartzite, and primary limestone, the mica-slate predominating. On the summit of Benbawn, quartzite reaches an elevation of 2395 feet.

The limestone beds which alternate with the mica-slate, frequently present a crystalline structure, and pass into granular marble; and in several localities, but particularly in the valley of Barnanoraun, north of Ballinahinch, there are thick beds of yellowish-green steatitic marble, alternating irregularly with bands of limestone of various shades of colour (Connemara marble).

The mica-slate district extends northward for a distance of eight miles to Blackwater bridge, where it terminates, and is succeeded, in an unconformable position, by a remarkable suite of Silurian rocks.

The first member of this series consists of a breccia composed of angular fragments of reddish-brown mica-slate, enveloped in a paste consisting of very small fragments of mica-slate. This breccia is stratified, and its thickness is unequal, varying from 50 to 150 feet. It is usually succeeded by brownish-red compact quartzose sandstone, which is stratified conformably with the micaceous breccia; its average thickness may be about 250 feet; this sandstone is followed by strata composed of gray compact quartzite about 300 feet in thickness, which, when slightly disintegrated, presents the character of quartzose sandstone. These strata are arranged in rather thick beds, some of which are very fossiliferous. In the line of section the characteristic fossils consist of—

Amphion brongniarti, n. s.
Asaphus latifrons.
Bellerophon trilobatus? (cast
Orthoceras gregarium.
,, tenuicinctum.
,, virgatum.
Turritella gregaria.?
,, obsoleta.?
Atrypa lacunosa.
,, hemisphærica.
Orthis canalis.
,, orbicularis.
Modiola semisulcata.
Favosites polymorpha.
Turbinolopsis bina.
Tentaculites ornatus.

But in other localities near the eastern boundary of the Silurian district at Thonlegee, on the northern declivity of Benleva mountain, and at Bohaun, south of Correen mountain, the characteristic fossils are,—

Amphion brongniarti, n. s.
Agnostus tuberculatus.
Bellerophon trilobatus.
Orthoceras gregarium.
Atrypa hemisphærica.
,, lacunosa, var.?
,, pulchra.
Orthis orbicularis.
Turritella gregaria.
Trochus lenticularis.
Atrypa affinis.
Leptæna depressa.
Modiola semisulcata.
Tentaculites ornatus.

and several others, with many new species.

In the line of section the fossiliferous quartzite is succeeded by thick beds of coarse conglomerate, having a base of gray compact quartz, with pebbles varying in size from one inch to one foot or more in diameter, the pebbles being composed of compact quartz, varying in colour from white to dark reddish gray. This conglomerate, which is not fossiliferous, alternates with a compact quartzose slate; the whole may be about 150 feet thickness near Blackwater bridge; but in other localities it is very thin, and towards the eastern extremity of the district it is altogether wanting. The conglomerate beds are succeeded by a series of strata of about 2000 feet in thickness, consisting of greenish-gray compact quartzite, and greenish-gray flaggy slate. At Tullyconnor bridge they are followed by a series of beds composed of dark gray clay-slate, alternating with gray quartzite, the slate predominating. This series may be about 700 feet thick; it contains numerous fossils, the most important of which are—

Calymene pulchella.
Amphion brongniarti, n. s.
Orthoceras filosum.
,, tenuicinctum.
,, virgatum.
Euomphalus lloydi, n. s.
,, perturbatus.
,, sculptus.
Atrypa navicula.?
Orthis canalis.
Orthis lunata.?
,, orbicularis.
,, plicata.?
,, sericea.
Leptæna depressa.
,, euglypha.
Psammobia rigida.
Favosites fibrosa.
Tentaculites scalaris.

In the eastern part of the district at Benleva mountain already mentioned, at Kilbride on Lough Mask, and at Ardaun, north of Lough Corrib, numerous fossils have been discovered in the schistose rock, and nearly in the same position as those which occur in the dark gray slate near Tullyconnor bridge, the most characteristic of which are—

Amphion brongniarti, n. s.
Turritella gregaria.
Euomphalus lloydi, n. s.
Lingula attenuata (var.?)
,, lata (var.?)
Atrypa affinis.
,, aspera.?
,, hemisphærica.
Orthis canalis.
,, costata.
,, flabellulum.
,, orbicularis.
,, plicata.?
,, pecten? (var.).
,, sericea.

Leptæna depressa.
,, lata.
,, tenuistriata.
Catenipora escharoides.
Favosites alveolaris.
,, fibrosa.
,, gothlandica.
,, multipora.
,, polymorpha.
Porites pyriformis.
,, tubulata.
Cyathophyllum turbinatum.
Turbinolopsis bina.
Tentaculites ornatus.
,, scalaris.

In the line of section the fossiliferous slates are followed by a series of beds, consisting of alternations of red clay-slate, greenish-gray clay-slate, and quartzite, altogether about 1600 feet in thickness without fossils. They are followed by a series of beds about 1000 feet in thickness, consisting of alternations of compact gray quartzite, alternating with a greenish-gray brecciated rock; near the top are two bands of gray subcrystalline limestone, one of which is 12 feet in thickness. This limestone is rarely fossiliferous, but in some localities it contains stems of encrinites, imperfect zoophytes, and rarely casts of *Orthis sericea.* The limestone bands are succeeded by a very remarkable coarse-grained conglomerate, composed of a base of rounded particles of quartz, very closely aggregated together, enclosing rolled masses of granite and compact quartz, varying in colour from light gray to reddish brown: some of the rolled masses exceed one foot in diameter, but the average range from four to ten inches in diameter. The granite is composed of red felspar, white quartz, and some hornblende, and is similar in composition and external character to the granite of Connemara, north of Galway Bay. Ascending in the series, the pebbles become smaller, and then the rock alternates with greenish gray, and occasionally purple slaty flags.

The granitic conglomerate series is of great thickness, probably upwards of 2000 feet; it occurs both on the south and north sides of Killery Harbour. The general dip is to the north, but at Tonatlew, north of the harbour, there is a synclinal axis, which axis forms the highest part of the Silurian series of the district; as, to the north of it, the conglomerate strata which occur to the south on the borders of Killery Harbour, appear at the surface forming the steep acclivity of Tievaree mountain. Hence it would appear that the entire thickness of the Silurian series in the Killery district amounts to about 9000 feet. But from the fossils discovered, it would appear to be doubtful whether it should be classed with the upper or lower Silurian group, as the *Orthis flabellulum* and *Orthis sericea* of the lower occur abundantly among fossils which are usually considered to be characteristic of the upper Silurian series.

Mr. Griffith next directed the attention of the Section to the Silurian district on the east coast lately examined, extending through the counties of Waterford, Wexford, and Wicklow, the greater part of which had previously been considered by him to belong to the older slate series. He observed, that Mr. Weaver in his paper on the east coast of Ireland, published in the Geological Transactions, mentioned that certain fossils had been discovered at Knockmahon on the coast of Waterford; subsequently fossils had been discovered by Mr. Griffith, and also by Captain James, R.E., at Tramore Bay, Knockmahon and other localities on the same coast. But the positions in which fossils had been discovered being confined to the coast, Mr. Griffith had, on his Geological Map of Ireland, limited the extent of the Silurian series of Waterford to the sea coast. At the meeting of the Association at Cork, Mr. Oldham mentioned that he thought the Silurian series occurred on the coast of Waterford Harbour, both in Waterford and Wexford; in consequence Mr. Griffith was induced to commence an examination of the slate series, not only on the shores of Waterford Harbour, but extended the investigation throughout the schistose strata of the counties of Wexford and Wicklow; and in consequence Silurian fossils were discovered in several localities in both of those counties. In illustration of the succession of the strata, Mr. Griffith exhibited a section extending in a north-western direction from the sienitic granite at

Carnsore point on the coast of Wexford, crossing the quartz rock mountain of Forth, and afterwards the entire suite of the fossiliferous clay-slate which terminates on the eastern boundary of the great granite district of Wicklow and Wexford. The strata which form the lowest part of the series, and which rest on the granite of Carnsore point, consist of gray micaceous, or shining slate (probably metamorphic), alternating with beds of gray slaty quartzite. These strata are succeeded by the quartz rock of Forth mountain, situated close to the town of Wexford. This quartz rock is arranged in thick beds, alternating occasionally with shining slate; it is followed in an ascending order by alternations of red and greenish-gray clay-slate, with occasional beds of gray quartzite, and also with beds of greenish-gray brecciated quartzite, above which are strata consisting of dark gray clay-slate, with occasional beds of gray quartzose flags. These dark gray slates may be considered as the commencement of the fossiliferous strata; for, ascending in the series, the dark gray slate is found to contain in abundance Graptolites, apparently a new variety of the *Graptolites foliaceus*, which fossil has been discovered in several localities in the counties of Wexford, Wicklow, and also in Meath and Tyrone. Still proceeding north-westward in the line of the section, and apparently ascending in the series, the same dark gray slate continues, and in several localities in the same strike it was found to contain fossils belonging to the lower Silurian series, particularly the following:—

Trinucleus caractaci.
,, fimbriatus.
,, radiatus.
,, seticornis.
Calymene blumenbachii.
Asaphus corndensis.
,, latifrons.
,, marginatus.
Isotelus powisii.
Orthis actoniæ.
Orthis canalis.
,, protensa.
,, radians.
,, rugifera.
,, sericea.
,, testudinaria.
,, triangularis.
Fenestella milleri.
Favosites fibrosa.
Tentaculites annulatus.

The dark gray slate continues above these fossiliferous beds, when it is succeeded by a series of strata consisting of greenish-gray and red slates, with occasional beds of quartzite; these strata are frequently calcareous, and in such localities encrinite stems are abundant, and occasionally we find obscure casts of Orthides and Trilobites, with traces of Zoophyta, the specific characters of none of which were sufficiently perfect to be recognized. On the north shore of Waterford Harbour, these greenish-gray and red slates form a trough nearly in the centre of the district, to the west of which the dark gray clay-slates rise up from beneath, and extend to the eastern boundary of the great granite district of Wicklow already mentioned.

The strata throughout the whole of the slate district of Waterford, Wexford, and Wicklow, are very much disturbed and contorted; consequently it will be difficult to trace with certainty the same beds by following the strike; but judging from the similarity of the fossils found in Wicklow, Mr. Griffith was inclined to think that the same system of fossils occurs there.

Mr. Griffith further observed, that there was still a very extensive schistose district extending through the counties of Down, Armagh, Monaghan, Cavan, Louth, and Meath, in which no fossils had been hitherto discovered, excepting on the southern border, near Slane in the county of Meath, where Graptolites, similar to those of Wicklow and Wexford, had been discovered by him, and also Orthides. He thought it probable that the whole district was fossiliferous, and probably belonged to the same portion of the lower Silurian series to which we must attach the schistose district of Wicklow, Wexford, &c.

Notice of the Discovery of a large Specimen of Plesiosaurus *found at Kettleness, on the Yorkshire Coast. By* EDWARD CHARLESWORTH, *F.G.S.*

The subject of this notice had been found a short time previously in the lias shale, quarried for the manufacture of alum, in the Kettleness Cliff, a few miles north of Whitby; and the lessees of the works, Messrs. Liddell and Gordon, had permitted the author to remove it, for the purpose of examination, to the museum of the Yorkshire Philosophical Society. Its total length was fifteen feet; that of the head above two feet; the neck, double that of the head; length of the humerus, thirteen inches; length of femur, fourteen inches. The author observes, that the only published species exhibiting the above relative proportions of head and neck, is the *Plesiosaurus macrocephalus* of Conybeare, to which he supposes the present fossil must be referred. To agree however fully with the characters assigned to this species by Prof. Owen, the respective lengths of the femur and humerus should have been twelve and fourteen inches. He also finds the tail more depressed than it appears to have been in the celebrated specimen of *P. macrocephalus* belonging to the Earl of Enniskillen. The author in conclusion, regretted not having had time to make a more rigid examination of the Kettleness fossil, and stated his intention to publish a detailed account on some future occasion.

On the Discovery, by Mr. Searles Wood, *of an Alligator in the Freshwater Cliff at Hordwell, associated with extinct Mammalia. Communicated by* Mr. CHARLESWORTH.

A considerable portion of the skeleton of an alligator, to which Mr. Wood gives the specific name *Hantoniensis*, was discovered by this gentleman at Hordwell, in the summer of 1843. He found at the same time the teeth and jaws of a Pachydermatous Mammal, closely related to Hyracotherium, but not larger than a Hedgehog. Regarding these remains as indicating a new genus, Mr. Wood proposes the name *Microchœrus*, with the specific term *erinaceus*. Associated with the above fossils there were also discovered some portions of the jaws of a very small insectivorous animal, and two very remarkable teeth, referred by Mr. Charlesworth to an extinct genus of Seals.

Remains of various other extinct vertebrata were discovered on this occasion by Mr. Wood at Hordwell, including *Palæotherium* (teeth and bones), *Lepidosteus* (scales, jaws and vertebræ), the bone of a bird, with vertebræ referable probably to Ophidians and small Saurians, and incisor teeth of Rodents.

Mr. Charlesworth suggested the generic name *Spalacodon* for a small insectivorous animal, indicated by a portion of a jaw which Mr. Flower of Croydon obtained from Hordwell, and entrusted to Mr. Charlesworth for publication with Mr. Wood's fossils.

On the Bathymetrical Distribution of Submarine Life on the Northern Shores of Scandinavia. By Professor LÖVEN *of Stockholm. Communicated by* Mr. MURCHISON, *P.R.Geogr.S.*

By an examination of the sea-bottoms along the coasts of Norway, the author had arrived at the same conclusions as those established by Professor Forbes from researches in the Ægean Sea. After remarking on this, he says, "As to the regions, the littoral and laminarian are very well defined everywhere, and their characteristic species do not spread very far out of them. The same is the case with the region of florideous Algæ, which is most developed nearer to the open sea. But it is not so with the regions from fifteen to one hundred fathoms. Here there is at the same time the greatest number of species and the greatest variety of their local assemblages; and it appears to me that their distribution is regulated, not only by depths, currents, &c., but by the nature of the bottom itself, the mixture of clay, mud, pebbles, &c. Thus, for instance, the same species of Amphidesma, Nucula, Natica, Eulima, Dentalium, &c., which are characteristic of a certain muddy ground at fifteen to twenty fathoms, are found together at eighty to one hundred fathoms. Hence it appears, that the species in this region have generally a wider vertical range than the littoral, laminarian, and perhaps as great as the deep-sea coral. The last-named region is with us characterized, in the south by *Oculina ramea* and Terebratula, and in the north by Astrophyton, Cidaris, *Spatangus purpureus* of an immense size, all living, besides Gorgoniæ and the gigantic *Alcyonium arboreum*, which continues as far down as any fisherman's line can be sunk. As to the point where animal life ceases, it must be somewhere, but with us it is unknown. As the vegetation ceases at a line far above the deepest regions of animal life, of course the zoophagous mollusca are altogether predominant in these parts, while the phytophagous are more peculiar to the upper regions. The observation of Professor E. Forbes, that British species are found in the Mediterranean, but only at greater depths, corresponds exactly with what has occurred to me. In Bogoslan (between

Gottenburg and Norway), we find at eighty fathoms, species which, in Finmark (on the north), may be readily collected at twenty, and on the last-named coast, some species even ascend into the littoral region, which, with us here in the south, keep within ten to eleven fathoms."

These researches were undertaken simultaneously with those of Professor Forbes, and these authors arrived at similar results quite independent of each other.

On an Anomalous Structure in the Paddle of a Species of Ichthyosaurus. By H. E. Strickland, *M.A., F.G.S.*

The anomaly of structure described in this communication, consisted of an additional bone between the radius and ulna of the anterior extremity of an Ichthyosaurus. Two specimens had been found having this peculiarity, and it was suggested that it might indicate a specific peculiarity. In both the specimens the humerus was succeeded by three nearly equal-sized bones, and these by the usual irregular paddle-bones representing the metacarpals, the carpals, and the phalanges.

Queries and Statements concerning a Nail found imbedded in a Block of Sandstone obtained from Kingoodie (Mylnfield) Quarry, North Britain. Communicated by Sir David Brewster.

This communication, drawn up by Mr. Buist, consisted of a series of queries, with the answers that had been returned by different persons connected with the quarry, the inquiry being set on foot by persons present on the discovery of the nail or immediately afterwards. The following is the substance of the investigation.

1. *The circumstance of the discovery of the nail in the block of stone.*

The stone in Kingoodie quarry consists of alternate layers of hard stone and a soft clayey substance called "*till*;" the courses of stone varying from six inches to upwards of six feet in thickness. The particular block in which the nail was found, was nine inches thick, and in proceeding to clear the rough block for dressing, the point of the nail was found projecting about half an inch (quite eaten with rust) into the "*till*," the rest of the nail laying along the surface of the stone to within an inch of the head, which went right down into the body of the stone. The nail was not discovered while the stone remained in the quarry, but when the rough block (measuring two feet in length, one in breadth, and nine inches in thickness) was being cleared of the superficial "*till*." There is no evidence beyond the condition of the stone to prove what part of the quarry this block may have come from.

2. *The condition of the quarry from which the block of stone was obtained.*

The quarry itself (called the east quarry) has only been worked for about twenty years, but an adjoining one (the west quarry) has been formerly very much worked, and has given employment at one time to as many as 500 men. Very large blocks of stone have at intervals been obtained from both. It is observed that the rough block in which the nail was found must have been turned over and handled at least four or five times in its journey to Inchyra, at which place it was put before masons for working, and where the nail was discovered.

On the Relative Age and True Position of the Millstone Grit and Shale, in reference to the Carboniferous System of Stratified Rocks in the British Pennine Chain of Hills. By J. Rooke.

The object of this communication was to point out a supposed error in the order of the strata as laid down by geologists, and to show that the error originated in the neglect of a due consideration of what are called by the author the laws of a drifting process.

On the Toadstones of Derbyshire. By John Alsop.

In this communication, which was intended to illustrate and explain certain sections prepared by the author, allusion was made to recent mining speculations in Derbyshire, in which the object has been to find a continuation of the mineral veins underneath the toadstone beds, and it is mentioned as not surprising that beds so uncertain not only in thickness, but in locality, should daunt the enterprise of the miner, since a mere bed of clay varying from a few inches to a foot in thickness in one mine, becomes in the next mine twelve or fourteen fathoms thick, and in another a hard compact rock. The object of the paper was to prove this uncertainty, and to show that there are at least two if not three distinct beds of the singular rock called toadstone.

The author, alluding to the opinion of Mr. Hopkins, that when two beds of toadstone have been thought to exist, a fault has re-introduced the one, and thereby occasioned the mistake (an opinion since somewhat modified), states that in a section of Crick Cliff, what is at one shaft a thin bed of clay a foot thick, becomes within a short distance fourteen feet thick, and contains large nodules of compact toadstone, while the thick bed of toadstone actually sunk through at one shaft diminishes to a thin bed at the other mine, and this is clearly discernible, since the workings are connected and the trace of each bed is never lost sight of.

The author then proceeds to allude to different clayey beds uncertain in thickness, and when thickest, containing blocks of hard toadstone. One of these, the "great clay" of the Wirksworth district, is identified with another at Crick, by the situation of three beds of clay beneath. These clays are said to be well-known to the working miner and to be easily recognizable when they have been once seen. They are called (1) the "twenty-fathom clay," (2) the "bearing clay," occurring about seventeen fathoms below the former, and (3) the "tumbling clay," about five fathoms below the bearing clay, and remarkable for its undulating character.

It is stated that at Smitterton a thick bed of toadstone of twelve fathoms replaces a thin bed of clay at Crick and Wirksworth, there being at this place (Smitterton) a second toadstone similar to those at Crick and Wirksworth with a limestone resting upon it, also similar in character and containing similar fossils. There is also another bed, to all appearance another toadstone, but this was not made out distinctly; it is at the same distance from the toadstone as the twenty-fathom clay at the other places.

Account of the Grassington Lead Mines, illustrating a Model of the Mine.

By S. Eddy.

The model which this communication was intended to illustrate represented a portion of the Grassington Lead Mines near Skipton in the West Riding of Yorkshire, the property of the Duke of Devonshire, at whose request the model was exhibited. The mines are in the carboniferous series of strata, from which two-thirds of the whole quantity of lead raised annually in England is obtained.

It is well known that most of the lead veins in this formation in England are principally valuable when passing through the limestone bed, but to this general rule the Grassington mines form an exception, nearly the whole produce being obtained in the gritty beds, alternating with the limestone and shale. It is to be observed, however, that the veins, although numerous and extending over a large tract of moorland, are for the most part small and not very productive. It was considered that as a thick bed of limestone (thirty-six fathoms) succeeds the shale and gritstone in which the veins are worked, and is succeeded by a bed of shale, the produce would increase on reaching the limestone, but this has not proved to be the case. A trial is now going on for the purpose of exploring some of the principal veins below the shale.

Nearly all the veins in the Grassington district are what are termed "*Fault veins,*" that is, a vertical displacement of the strata has taken place, so that the same beds are found at different levels on the two sides of the vein, and the subsidence of the strata is generally on that side to which the veins incline, the amount of inclination or underlay of the vein being invariably much greater in the argillaceous beds than in the grit or limestone.

A depression of a few feet or two or three fathoms is considered most favourable for lead ore, but the displacement is sometimes much greater, causing grit or limestone on one side of the vein to be opposite to argillaceous beds on the other. In such cases the veins are rarely productive, although the principal vein shown in the model is an exception to this rule.

The general matrix of the ore (the veinstone) is calcareous spar, fluor spar, barytes, and occasionally calamine, and when the amount of the fault is so considerable as to bring beds of different mineral character in contact, fragments of the containing rocks form a great portion of the contents of the vein.

The portion of the mine modelled represents the richest piece of ground as yet opened in these mines, and includes two extensive fault veins, together with a piece of ground from which some very rich slickensides have been obtained. All the ore found near the slickensides is much more refractory in the furnace, and of less produce than that raised at a distance from it. The gritstone between the two veins from the points where the slickensides commenced is also quite altered in its character and appearance.

The model was on a scale of one inch to five fathoms, but the veins and a bed of coal represented were on a larger scale. There was exhibited a transverse section of the mining ground for 138 fathoms, a longitudinal section of eighty fathoms, and a depth of seventy fathoms.

On the Palæozoic Rocks of Scandinavia and Russia, particularly as to the Lower Silurian Rocks which form their true Base. By R. I. MURCHISON, *F.R.S., P.R.Geog.S., &c.*

The author commenced by giving a general sketch of the Palæozoic succession in Russia, showing that however perfect in exhibiting a series of Silurian, Devonian, Carboniferous and Permian rocks, it was defective at its base, since between the Silurian rocks of the governments of St. Petersburg and Reval, and the crystalline rocks of Finland, there occurs a wide and deep bay of the sea; and in tracing the lower edge of the Silurian rocks from St. Petersburg to Archangel on the N.E., their junction with the underlying series is equally hidden by large accumulations of detritus. There is also another reason why this passage cannot be made out, arising from the condition of the Silurian rocks, which soft, unaltered, and, in truth, unfathomed along the northern edge of the Baltic provinces, come in contact towards the N.E. with eruptive trap rocks, and have thereby undergone metamorphosis over an extensive tract of country, so that on the whole the exact manner in which these ancient deposits repose on the pre-existing rocks cannot there be distinctly observed.

Scandinavia, on the other hand, presents a very clearly defined base-line, which is exposed in different sections, both in Sweden and Norway. In illustration, the author first mentioned several instances in Sweden, where the very lowest Silurian beds containing no other fossils than fucoids, repose horizontally upon the crystalline rocks of a more ancient period; and he also cited localities where the lowest Silurian rocks are to a great extent *formed out of the detritus of those more ancient rocks.*

In the first-formed or gneissose slates of Scandinavia no organic remains have been discovered. Taking into account this fact, and adopting the prevailing theory, that the first solid envelope of the globe was formed under a heat so intense as to preclude the possibility of the existence of animal life, Mr. Murchison proposes the term "*Azoic**" for this group of deposits, as expressing the fact that no organic remains have yet been discovered in them. The Azoic group is immediately followed by the great palæozoic series, commencing with the lower Silurian, and terminated in the ascending order with the rocks of the Permian system.

Believing however, that metamorphism has frequently imparted a crystalline character to sedimentary strata, containing organic remains, in illustration of which view he referred to observations he made in company with Dr. Forchhammer (see memoir in this volume), Mr. Murchison alluded next to the importance of drawing a marked distinction between this more modern class of crystalline rocks and that which he terms Azoic. He mentioned as an instance, that in Norway there are extensive transition districts replete with granite, porphyry, and greenstone, all erupted subsequent to the deposition of the Silurian strata, which they have altered, and which are always distinguishable from the ancient gneiss and granitic gneiss, upon which they repose.

Referring for the further illustration of his views to a section across Sweden and the Baltic Sea, to the tract of Russia east and south of St. Petersburg, Mr. Murchison proceeded to state, that the lower Silurian rocks of both countries contain a similar group of organic remains, including many species occurring in deposits of the same age in the British Isles. He also mentioned that in Sweden, at least throughout the central and southern provinces, as well as in the Baltic provinces of Russia, no

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* Hypozoic of Phillips.

true upper Silurian rocks are found; so that the whole of these highly fossiliferous regions belong to that period of animal life *at which vertebrated animals did not exist.* This absence of even the lowest of the vertebrata in the inferior Silurian rocks, an absence which is total, so far as can be inferred from the researches of geologists in all parts of the world, gives them a true "*Protozoic*" character; and this condition of things was mentioned by the author as a strong reason for concluding, that the epoch in question was the earliest in which animal life was developed. It was also shown that the Swedish and Norwegian sections afford ample illustration of the fact, that if fucoids or marine vegetables did not precede the first-formed animals, they were certainly contemporaneous with them; thus confirming the view, that the animals found in a fossil state in these protozoic rocks must have been provided with vegetable sustenance.

The almost total absence of upper Silurian rocks in Southern and Central Sweden, and in the mainland of the Baltic governments of Russia, was explained by Mr. Murchison on the hypothesis of such tracts having undergone extensive elevatory movements, which placed them beyond the influence of depository action during the succeeding period; and he mentioned that this view is rendered highly probable by the discovery of true upper Silurian rocks in the Baltic islands of Gothland, Ösel, and Dago, which are made up of corals and molluscous remains, similar to those of the Wenlock and Ludlow rocks of the British Islands; the whole reposing on a band of limestone, which occupies exactly the same place in the geological sequence, and contains the same fossils (*Pentamerus oblongus*), as the Woolhope and Horderly limestone of Siluria. This calcareous band appears therefore to be the connecting link between the lower and upper Silurian rocks in Scandinavia, just as in the typical districts of our own country. Beneath it appear black flags, limestones, schists and sandstones, with such fossils as *Trinucleus Caractaci, Asaphus Buchii, A. tyrannus,* Agnostus, Sphæronites, Orthis, and certain chambered shells, greatly resembling as a group, and often specifically identical with the fossils of the same age in the British Isles; while above are many concretionary coralline limestones and calcareous flagstones and shales, charged with the common upper Silurian species.

In the district around Christiania and in the islands of its bay or fiord, these two divisions of the Silurian system are beautifully exposed in numerous undulations and dislocations of the strata, and they are there so bound together by zoological and mineral transitions, that they constitute a very distinct natural group, in which the coralline masses of the upper division are singularly analogous to the best-developed types in England (the Dudley and Wenlock), and like them, are overlaid by flag-like strata.

The author next alluded to his discovery at Christiania of an ascending succession, in which the upper Silurian strata are seen to pass under great escarpments of red flagstone, sandstone, and conglomerate, which, covered by porphyry, occupy a considerable breadth of high land, and repose, as in a great basin, upon the upper Silurian rocks; and this group of rocks in Scandinavia has exactly the appearance of the *old red sandstone* of the North of England and Scotland. The details of this succession of Norwegian palæozoic rocks will be subsequently presented to the Geological Society of London, and a brief abstract of the principal facts, as explained by Mr. Murchison to the last meeting of the Society of Scandinavian Naturalists, will be published in the volume of the Transactions of that body.

Mr. Murchison then proceeded to give a rapid sketch of some of the leading features of Russian Palæozoic Geology, showing in the first place, that the Devonian rocks there occupied a space larger than the whole area of Great Britain, and exhibit at the same time the most instructive development of the system yet discovered. Reposing upon Silurian rocks, and overlaid by true carboniferous limestones, they contain the same fossil fishes as are found in Scotland, and the same molluscous remains and corals as the contemporaneous strata of Devonshire, the Boulonnais, and the Rhenish provinces. The Devonian system Mr. Murchison considers as the earliest great storehouse of fishes, a few species only having been discovered in the uppermost Silurian rocks.

The surprising coincidences between the organic remains of the carboniferous limestone of Russia and of the British Islands, and the perfect agreement between numerous species of shells found in the Westmoreland and Yorkshire dales on the one hand, and the tracts of Siberia on the other, was next adverted to as a strong proof, in addition to that derived from the wide spread of the species of coal-plants, that the earlier epochs of the earth's history were marked by much more equable and widely diffused climatal conditions than now obtain. Mr. Murchison then concluded by summing up the views arrived at by his coadjutors (M. de Verneuil and Count Keyserling) and himself concerning the newer palæozoic rocks, explaining that the Permian strata* (so named from their great development in the ancient kingdom of Permia) were connected with the lower palæozoic deposits (the Carboniferous, Devonian and Silurian), not only by the *generic facies* of the fauna, but also by species of Producti, Terebratulæ, &c., which lived in earlier periods. The land plants found in these strata approach also very nearly to those of the carboniferous rocks, and according to M. Adolphe Brongniart, are in some instances identical with them.

The termination of the Permian system, on the contrary, is marked by an entire change in animal life, and so far as we yet know, in vegetable life also, the fossils of the red marls, the muschelkalk, and the keuper (the *trias* of foreigners and the upper new red sandstone of English geologists) being wholly distinct from those of the palæozoic series

Copies of a tabular list of the organic remains of the Permian system, as prepared by Mr. Murchison and M. de Verneuil, and intended to form part of a work to be published on the geology of Russia, were then laid before the Section.

New Swedish and Norwegian Maps.—Mr. Murchison next called attention to a lithological map of Sweden, now in preparation, in which a great number of the ancient crystalline rocks are distinguished from each other by different colours, and their flexures marked. A portion of this map had been shown to Mr. Murchison by the Baron Berzelius, under whose superintendence it will be published. Allusion was made also to a geological map of the Christiania district, by Professor Keilhau, and to a new geological map of the northern part of Norway by the same author.

A Geological Map of the British Isles and part of France was exhibited by Mr. J. Knipe.

This map, the author states, was intended to supply a want that existed at the time he undertook the work, when the separately published Geological Maps of England and Wales, Scotland and Ireland were imperfect and not constructed to any uniform scale, or according to any uniform method of colouring.

On the Exeter Amygdaloid. By the Rev. David Williams.

The author remarked that so long as twenty-five years ago, Mr. Greenough had pointed out the difficulty of distinguishing between the red marl and the toadstone of Heavitree, and stated, that judging from the specimens he exhibited to the meeting, and from the sections represented by his diagrams, the trappean matter did not appear to him to have been injected into the variegated marl and sandstone. Mr. Williams considered that these specimens and sections exhibited every gradation, from a perfectly fused sandstone, to a partially freckled surface caused by the incipient process of conversion, and that in this respect they presented the appearances seen at the boundary walls of granite veins, indicating the process of reduction always in advance of the lava sea within, while its efforts at reducing the bounding rocks contained in itself the elements of compensation and correction in thus working out safety valves and channels of communication with the surface of the globe over the several volcanic areas.

The author remarked with reference to these changes, that the greater or less amount of alteration and the presence or absence of granite vein-like processes or cavities eroded in the adjacent rocks, would enable an observer to distinguish whether any igneous rock had been generated and crystallized *in situ*, or was a contemporaneous and erupted product, and in illustration quoted the section of the Raddon quarry, where the presence of three thin seams of unfused grit, ten and twelve feet long, give the trap to that extent only the appearance of bedding. He argued that the presence of these lines of sandstone perfectly insulated in the amygdaloid was inexplicable on the hypothesis of injection, but was a natural result of fusion, certain portions of

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* The *Permian system* comprehends the formation of the lower new red sandstone (Rothe-todte-liegende), Magnesian limestone (kupfer-schiefer and zechstein), and also a portion of the overlying red sandstone, which has been hitherto inaccurately grouped with the trias.

the rock escaping conversion on the diminution of the temperature. On three sides of the quarry the variegated sandstone was observed resting on the trap without having been dislocated or deranged by it, and this also appeared to Mr. Williams only to be explained by supposing tranquil fusion and conversion. "If the amygdaloid," he said, "had in either case been forcibly protruded, it must have displaced very many millions of cubic yards of sandstone and caused great derangement; yet there was not a particle of evidence of anything of the kind having taken place." The author concluded by stating that he had discovered instances of the process of fusion and conversion in all the slates, sandstones and limestones of South Devon and Cornwall, in the mountain limestone of the Mendips, and the variegated sandstones about Exeter, all of them explicitly and emphatically negativing the hypothesis of injection.

Notice respecting the Discovery of Gold Ores in Merionethshire, North Wales. By ARTHUR DEAN, *C.E.*

The author stated, that in 1843 he discovered some rich gold ores at the Cwmheisian mines near Dolgelly. Further researches proved that a complete system of auriferous veins exists throughout the whole of the Snowdonian or lower Silurian formations of North Wales.

The structure of this district is very singular, consisting of an immense number of alternate and parallel beds of igneous and sedimentary rocks, traversed by vast numbers of mineral veins and trap dykes.

These mineral veins are of three periods of formation; those of the first period have an average bearing from S.E. to N.W., with a dip to the north; they contain quartz impregnated with ores of argentiferous galena, copper, iron, and blende, &c. The veins of the second period have a general bearing N.E. and S.W., with a northern dip, and contain carbonates and sulphates of barytes and lime, galena, blende, &c.

The third set, comprising the auriferous veins, traverse both the other two, and have an average bearing of N.N.E. and S.S.W., and like the others, with a north dip. These veins are very numerous, and are filled with argillaceous substances, iron pyrites, and iron and blende ores. In width they vary from ⅛th of an inch to 6 or 8 inches, but sometimes expand to 2 or 3 yards. In many cases they split into a great number of minute branches. Where the auriferous veins traverse quartzose veins of the first series they are generally very productive of gold, the quartzose veins, if metalliferous, becoming enriched on the south side of the intersection. The sides of the auriferous veins, where they pass through quartzose veins, are generally cellular, and in these cells the gold, in a fibrous form, is for the most part deposited, accompanied by various ores of iron, blende, galena, &c.

In almost all cases in this district, where the mineral veins intersect each other, the intersected vein, if enriched at the junction, is productive only on the south side of the intersection, while it dips towards the north; and the intersecting vein, if also enriched, carries its ore from the point of intersection towards the north. Veins dipping south are almost always poor.

If a vein runs east and west, and the strike of the strata be north and south, the courses of ore follow the dip of the strata most favourable to their production.

Some of the gold ores discovered produce from 3 dwts. to 60 ounces of gold per ton of ore as broken; and some of the washed sulphurets of lead contain lead, 75 per cent; silver, 40 ounces; gold, from 2 to 20 ounces per ton.

Observations on the Stratification of Igneous and Sedimentary Rocks of the Lower Silurian Formation in North Wales. By ARTHUR DEAN, *C.E.*

In this communication the author stated his opinion that the igneous and sedimentary rocks of North Wales were for the most part of contemporaneous origin, the igneous rocks being regularly interstratified with the others, and not presenting any appearance of having been subsequently injected between the strata. Sometimes at least fifty alternations of parallel beds of igneous and sedimentary rocks may be found within the distance of a mile, varying respectively from one foot to sixty yards in thickness. In many cases also several beds of igneous rocks rest upon one another without the intervention of sedimentary rocks, such beds occasionally thinning out and disappearing.

These masses of igneous and sedimentary rock are traversed by numerous trap dykes or veins, often accompanied (always on the *north* side) by mineral veins, to which they serve as the under walls. The trap dykes generally dip northward.

Channels of slate several yards wide inclosing mineral veins are also frequently found; the slate is highly laminated, and the laminæ are parallel to the dip of the vein.

On the Explanation of certain Geological Phænomena by the Agency of Glaciers. By EDMUND BATTEN, *M.A.*

The object of the author in this communication was chiefly to excite discussion concerning the transport of large boulders and erratic blocks observed in different parts of Europe. His account was restricted to the gigantic boulders of Switzerland and the shores of the Baltic, and the erratic blocks traceable to the Grampian chain of Scotland. The former have been frequently described, and are considered by the Swiss geologists to have been conveyed by immense glaciers extending across the great valley of Switzerland; and near Edinburgh, appearances are observable which seem to indicate something like a similar cause having acted. It is a question, however, whether any theory of glacier motion will account for the passage of glaciers over these districts, and the improbability of a great extent of glaciers moving like a river across a country was pointed out. Allusion was then made to the iceberg theory, and its greater probability as a means of transporting heavy blocks; and the author concluded by enforcing the necessity of numerous observations, with a view to the solution of the problem.

On the Occurrence of Marine Shells in the Gravels of Ireland. By THOMAS OLDHAM, *M.R.I.A., F.G.S.*

The author commenced by noticing the prevalence of gravel and diluvial deposits in Ireland, where they occur in long, low rounded ridges called Eskars, which stretch for many miles in nearly a right line; or in detached rounded hills, or forming undulating grassy plains. These gravels have hitherto been considered not to contain any organic remains, and have been carefully distinguished from some deposits of clay containing marine shells which have been noticed in several places along the coasts, at elevations varying from 50 to 300 feet above the present level of the sea. Mr. Oldham did not consider this distinction well-founded. There were with the gravel deposits, patches of clay identical, in general mineral character and in the pebbles of the transported blocks which they contained, with those known to contain marine shells; and similarly, with the clay deposits, were layers of gravel, consisting of the same ingredients, and similarly arranged with the gravels of the undoubted eskars. Tracing further, he had extended the range of these fossiliferous clays, finding them in very many places, and in the centre of the island as well as along the coast; and at elevations above the present sea level of 200 to 600 feet; in several cases also in distinct eskars. Taking these facts as proof of a general alteration of level, he showed two maps, on which were represented the amount of land which would be visible were this alteration to have taken place to the extent of 1000 feet and 500 feet. In the former case what is now Ireland would only have existed as a few small scattered islands in the north and south; and the same would have been, in a general view, the case, if the alteration were only to the extent of 500 feet elevation or depression.

These deposits the author referred to the æra of the Newer Pliocene or Pleistocene, from the occurrence of the characteristic shell, the *Nucula oblonga* (Brown); with this was found the *Astarte gairensis*, and about twenty species now existing in the adjoining seas.

Under these so-called diluvial deposits the rocks were almost invariably found polished, furrowed and scratched; the edges of the projecting beds rounded off and smoothed, and the whole ploughed up in parallel lines. These scratches were to be found nearly at the present level of the sea, and also at very considerable elevations above it.

On the Physical Character and Geology of Norfolk Island. By Capt. MACONOCHIE, *R.N., K.H.*

The group of which Norfolk Island is the principal is situate in lat. 29° 2′ S. and 168° 2′ east long., 900 miles E.N.E. of Sydney, and 1350 N.E. from Cape Pillar in

Van Diemen's Land. Norfolk and Philip Islands, the largest of the group, are about six miles distant from each other, and about a dozen others, the Nepean and Bird Islands, are little more than dry rocks distributed among them. Norfolk Island is not quite 5 miles long with a medium breadth of about 2½ miles, and its superficies is said to be 8960 acres; its greatest elevation is the double summit of Mount Pitt, 1050 feet high; its sea front is high and precipitous, presenting cliffs of 200 and 250 feet in height, and the small streams which occupy the ravines in winter fall in cascades 30 or 50 feet high into the sea. Philip Island is about 1¼ mile long, with an average breadth of ¾; its most elevated point is probably 200 or 300 feet less than that of Norfolk Island. It is everywhere precipitous, furrowed by deep channels and densely wooded, though the timber is small and of little value. Both these islands are masses of porphyry much decomposed on the surface; and boulders of compact greenstone are abundant in both, especially in the fields and water-courses of Norfolk Island, where they are employed as building materials; they are also found imbedded in the porphyry at the greatest depths to which the rock has been penetrated by wells or exposed in ravines. Near the south-east extremity of Norfolk Island are extensive beds of sand and limestone resting on the porphyry; the limestone, which is the lowest formation, is from 12 to 20 feet thick, and occupies about 20 acres of comparatively flat land; in two places it has been fractured and upheaved from an angle of 10° to an absolute verticality. It is thin-bedded, the laminæ being usually 1 to 3 inches thick, of fine quality, slightly mixed with sand, but yielding 90 per cent. of lime; the sandstone appears to be entirely a modern formation, lying upon and against the dislocated limestone; the bar and projecting rocks along the whole of the south-east front are composed of it, but it is nowhere above 6 feet thick; below it is found an unctuous black clay full of vegetable remains, especially the leaves and seeds of pines and other island trees. The sandstone is only compact on the coasts where it is still forming; it contains marine shells and incrusts the boulders of greenstone on the coast. Being porous and filled with saline particles, it forms a bad building stone, the houses built of it requiring to be rough cast with lime. Opposite the settlement which is placed on these beds, and about 600 yards from the beach, Nepean Island rises to the height of 50 feet; it is about a quarter of a mile long, and of a horse-shoe shape open to the east. The limestone of which this island is composed is used for the shafts of chimneys, its east and south-east beach is formed of sandstone. No water has been found in it, and its vegetation has within the last few years almost disappeared, owing to a colony of rabbits, which having destroyed everything edible, have now themselves perished. It is reported that in 1793 this island was only a boat's length from Norfolk Island, but that in 1797 two severe earthquake shocks were experienced, by the second of which the nearer point of Nepean was submerged, and the channel altered to its present form. The rocks which pave the channel between these two islands are almost all limestones, whilst elsewhere they are porphyritic. The Bird Islands are rocks of porphyry distributed along the north shore of Norfolk Island; they are of no œconomic value, and are tenanted only by sea birds.

On the Communication between the Atlantic and Pacific Oceans, through the Isthmus of Tehuantepec. By Signor GAETANO MORO. *Communicated by* Mr. MURCHISON, *P.R.Geogr.S.*

It is considered by Signor Moro, who has carefully surveyed the district, that the communication between the Atlantic and Pacific Oceans might be accomplished in several ways, by taking advantage of the rivers on the Isthmus of Tehuantepec, which flow on one side into the Pacific, and on the other into the Gulf of Mexico, and in a manner far more advantageous than by either of the proposed routes by Nicaragua or Panama. This new line is considerably to the north of the others, and the country is said to be rich in the most valuable kinds of wood.

This work being published, can be consulted by all geographers.

On the Fish River of the North Polar Sea. By RICHARD KING, *M.D.*

The author stated that the source of the Fish River was discovered by Hearn, during his memorable journey to the Polar Sea, and that Captain Sir John Franklin, having learnt from an Indian named Blackmeat that the outlet of this river was in

Regent's Inlet, it was selected in 1833 as the route to be followed in seeking Captain Sir John Ross and his party. Ultimately, however, another river, now known as the "Great Fish" River, was preferred, so that the "Fish" River was not explored. In 1836, the author proposed to Government that a small expedition should be sent out to survey the portion of North-eastern America yet unknown, and that the Fish River should be the line of route, but Captain Sir John Franklin, then, for the first time, expressed a doubt with regard to the outlet of the river, which he thought to be in the Atlantic Ocean, and not the Polar Sea. He also suggested that the features of the river at its source were by no means the same as had been mentioned by the Indian above alluded to.

The author endeavoured to show, by adducing the evidence of the Chippewyan and Copper Indians and the Fur Traders in support of Blackmeat, that sooner or later this river will form a prominent feature in the survey of the unexplored Polar lands, as affording the means of connecting the discoveries of Messrs. Dease and Simpson on the one side, with those of Captain Sir E. Parry on the other. He considered that the sea of Regent's Inlet could thus be traced upwards, and its boundaries on either side explored, while a knowledge of Melville Peninsula, and the actual character of North Somerset (whether insular or peninsular) would also be determined. The author urged in conclusion, that being thus so near the crowning-work of the labour of three centuries, it would be unreasonable to stop, since one short summer would complete the survey.

ZOOLOGY AND BOTANY.

A Catalogue of Birds observed in South-Eastern Durham and in North-Western Cleveland. By JOHN HOGG, *M.A., F.R.S., F.L.S., &c.*

MR. JOHN HOGG, in this catalogue, made some physiological observations on the organization, and many remarks on the habits and geographical range of the birds which have been noticed in the parts of Durham and of Yorkshire, to which he limited himself. This district, comprising about 320 square miles, is so varied in the nature of the soil and water, that no less than 210 species (namely, 109 *land*-birds and 101 *water*-birds) are recorded as frequenting it,—a number indeed which is found to amount to only *seven* species *fewer* than *two-thirds* of the entire number of the British birds.

The author has been induced to make a few changes in the nomenclature of certain birds where the names have either been erroneously given or misapplied. And in respect to the arrangement adopted, he stated, that "it appeared to him to be more advisable to incorporate Cuvier's system in his present memoir, with that classification subsequently instituted by some of our English ornithologists, making at the same time certain modifications in both, than to use the latter alone as Mr. Yarrell has done." Also the author introduced *three* families, viz. Upupidæ, Recurvirostridæ and Procellariadæ, from the Prince of Musignano's "New Systematic Arrangement of Vertebrated Animals," in the Linnæan Transactions, vol. xviii. And the new tribes, Planicerirostres, Tecticerirostres, Cutinarirostres, Spathulirostres, Diversirostres, Cuspidirostres, Sulcirostres, Tubinarirostres, Medionarirostres, Subulirostres, &c. that he himself has added, are characterized, according to the views of Linnæus, from variations in the *bill*; and thus they tend to complete a *Rostral* classification.

The following is a sketch of the classification which is necessarily here abstracted, for the purpose of showing the modifications in the author's arrangement.

Division I.—AVES TERRESTRES.
Order I. RAPTORES.
Tribe 1. *Planicerirostres.*
Subtribe 1. *Diurni.*
Families.—1, *Falconidæ*; 2, *Buteonidæ*?
Tribe 2. *Tecticerirostres.*
Subtribe 2. *Nocturni.*
Family *Strigidæ.*

Order II. Insessores.
Tribe 1. *Dentirostres.*
Families.—1, *Laniadæ;* 2, *Muscicapidæ;* 3, *Merulidæ;* 4, *Ampelidæ;* 5, *Aëdonidæ;* 6, *Paridæ;* 7, *Motacillidæ;* 8, *Anthidæ.*
Tribe 2. *Conirostres.*
Families.—1, *Alaudidæ;* 2, *Emberizidæ;* 3, *Fringillidæ;* 4, *Loxiadæ;* 5, *Sturnidæ;* 6, *Corvidæ.*
Tribe 3. *Cuneirostres.*
Subtribe 1. *Scansores.*
Families.—1, *Picidæ;* 2, *Sittidæ.*
Tribe 4. *Curvirostres.*
Family *Cuculidæ.*
Tribe 5. *Tenuirostres.*
Subtribe 2. *Anisodactyli.*
Families.—1, *Certhiadæ;* 2, *Upupidæ.*
Tribe 6. *Fissirostres.*
Families.—1, *Halcyonidæ;* 2, *Hirundinidæ;* 3, *Caprimulgidæ.*

Order III. Rasores.
Tribe 1. *Cutinarirostres.*
Family *Columbidæ.*
Tribe 2. *Convexirostres.*
Families.—1, *Phasianidæ;* 2, *Tetraonidæ.*

Division II.—AVES AQUATICÆ.

Order IV. Grallatores.
Tribe 1. *Pressirostres.*
Families.—1, *Charadriadæ;* 2, *Hæmatopodidæ.*
Tribe 2. *Cultrirostres.*
Family *Ardeidæ.*
Tribe 3. *Spathulirostres.*
Family *Plataleidæ.*
Tribe 4. *Longirostres.*
Families.—1, *Recurvirostridæ;* 2, *Scolopacidæ.*
Tribe 5. *Diversirostres.*
Subtribe *Macrodactyli.*
Families.—1, *Rallidæ;* 2, *Lobipedidæ.*

Order V. Natatores.
Tribe 1. *Lamellirostres.*
Families.—1, *Anseridæ;* 2, *Anatidæ;* 3, *Fuligulidæ.*
Tribe 2. *Serrirostres.*
Families.—1, *Mergidæ;* 2, *Carbonidæ.*
Tribe 3. *Cuspidirostres.*
Subtribe *Brachyptera.*
Family *Colymbidæ.*
Tribe 4. *Sulcirostres.*
Family *Alcidæ.*
Tribe 5. *Tubinarirostres.*
Family *Procellariadæ.*
Tribe 6. *Medionarirostres.*
Family *Laridæ.*
Tribe 7. *Subulirostres.*
Subtribe *Longipennes.*
Family *Sternidæ.*

Report on the Birds of Yorkshire, prepared at the request of the Yorkshire Philosophical Society. By T. Allis.

This communication added the following to the before-recorded birds of Yorkshire. The Golden Oriole, a fine female specimen, shot near the Spurn Lighthouse in 1834; Fire-crested Wren, shot at Wood End, near Thirsk; Bearded Titmouse, from the neighbourhood of Huddersfield; Reed Warbler, Black Redstart, several specimens of which were taken by a bird-catcher near Leeds; the Stock Dove, killed near York, and occurring not unfrequently near Sheffield; it has also been seen in Feversham Park; Little Bittern, shot at Birdsall, near Malton; Polish Swan, killed near Bridlington; Gullbilled Tern, taken alive near Leeds; and the Ivory Gull, shot some years ago off Scarborough by a gentleman resident in York. The report was remarkable for the number and variety of marine birds reported to occur about Huddersfield and Barnsley, apparently in a state of transition from the east to the west seas; as also for recording the last instances of the occurrence of that noble bird the Great Bustard, which has now been extinct about twenty years in the county of York; it also notices the great diminution in number, of many species formerly plentiful, and which, in the course of a few more years, will also probably be numbered with the extinct; and has added numerous individuals to those already recorded of many of the rarer species; also a notice of the time of arrival of many of our summer visitants, from the pen of John Heppenstall of Sheffield, and a register of the arrival and departure of the swallow tribe, from the pen of W. Gott, Esq. of Leeds: the number of Yorkshire species appears to be 252.

Periodical Birds observed in the Years 1843 *and* 1844 *near Llanrwst, Denbighshire, North Wales. By* JOHN BLACKWALL, *F.L.S.*

Birds.	Appeared.	Disappeared.
	1843.	1843.
Sand Martin, *Hirundo riparia*	…………	Sept. 25
House Martin, *Hirundo urbica*	…………	Oct. 12
Swallow, *Hirundo rustica*	…………	,, 16
		1844.
Woodcock, *Scolopax rusticola*	Oct. 6	April 5
Redwing, *Turdus iliacus*	,, 12	March 27
Fieldfare, *Turdus pilaris*	,, 30	April 1
Siskin, *Fringilla spinus*	Nov. 3	
	1844.	
Pied Wagtail, *Motacilla alba*	March 14	
Tree Pipit, *Anthus arboreus*	April 7	
Yellow Wren, *Sylvia trochilus*	,, 8	
Black-cap, *Sylvia atricapilla*	,, 13	
Sand Martin, *Hirundo riparia*	,, 16	Sept. 10
Wheat-ear, *Saxicola œnanthe*	,, 17	
Swallow, *Hirundo rustica*	,, 17	
Common Sandpiper, *Totanus hypoleucos*	,, 20	
Wood Wren, *Sylvia sibilatrix*	,, 20	
Redstart, *Sylvia phœnicurus*	,, 22	
House Martin, *Hirundo urbica*	,, 23	
Cuckoo, *Cuculus canorus*	,, 23	July 1
Pied Flycatcher, *Muscicapa luctuosa*	,, 25	
White-throat, *Sylvia cinerea*	,, 27	
Winchat, *Saxicola rubetra*	,, 29	
Land Rail, *Gallinula crex*	,, 30	
Pettychaps, *Sylvia hortensis*	May 1	
Swift, *Cypselus murarius*	,, 10	August 25
Sedge Warbler, *Sylvia phragmitis*	,, 12	
Red-backed Shrike, *Lanius collurio*	,, 12	
Goatsucker, *Caprimulgus europæus*	,, 17	
Spotted Flycatcher, *Muscicapa grisola*	,, 18	Sept. 17

A Monograph of the Sub-family Odontophorinæ, or Partridges of America. By J. GOULD, *F.R.S., &c.*

The subjects of the present monograph are interesting from their probable utility to man whenever the countries of which they are denizens shall come under the dominion of civilization, as well as from their being expressly adapted for naturalization in Europe; many of the species are sufficiently hardy to brave the severity of our winters, and are, therefore, likely to thrive in situations suitable to the partridge and quail. All the members of the group are strictly American, and by far the greater number of the species natives of that portion of the country lying between the 30th degree of north latitude and the equator. Four species are included in the Fauna of North America, and it is these in particular that Mr. Gould considers most likely to thrive in Europe. Thirty species of this group are now known to Mr. Gould, two only of which were included in the works of Linnæus, and nine in the 'General History of Birds,' published by Latham in 1823. And even in the late revision of the subject by Messrs. Jardine and Selby in their 'Illustrations of Ornithology,' the number of species was only increased to eleven. Vieillot was the first who conceived the propriety of separating one of the members of the present group from the old genera *Tetrao* and *Perdix*, proposing the term Odontophorus for the *Tetrao Guianensis* of Gmelin; subsequently Stephens and Wagler proposed a further subdivision of the group, the former proposing the term Ortyx for the well-known Virginian partridge, *Perdix Virginianus*, and the latter that of Callipepla, the type of which is the *Ortyx squamata* of Vigors. If it be admitted that the American partridges constitute more than one genus, the genera must not be confined to three or four, but must extend at least to six. Mr. Gould further remarks that the partridges of America form a well-defined family, distinguishable from the grouse and partridges of the Old World in many particulars, among which may be intimated the total absence of any spur or spur-like appendage on the tarsi, and by the possession of teeth-like processes on the edges of the under mandible. The subject was fully illustrated with drawings of most of the species.

On the Fishes of Yorkshire. *By* T. MEYNELL, *F.L.S.*

The total number of species which have been detected as inhabiting the shores, or frequenting the freshwaters of Great Britain, is stated by Mr. Yarrell to be about 250, of which number Mr. Meynell mentioned 140 species as frequenting the waters of Yorkshire. Amongst these 140 species, the following appear to be most worthy of note:—The Greater Weever (*Trachinus Draco*), the Sapphirine Gurnard (*Trigla hirundo*), the Piper (*Trigla Lyra*), the Norway Haddock (*Sebastes Norvegicus*), the Sea Bream (*Pagellus centrodontus*), and the four-toothed Sparus (*Dentex vulgaris*), are all rare upon our coast.

Ray's Bream (*Brama Raii*) is found plentifully in some years at Redcar, generally left upon the shore by the receding tide, as many as twelve having been found in a morning: it only, however, occurs between October and December. One specimen only was found last year, and none the year before. A specimen of the Sword Fish (*Xiphias gladius*) was caught in Filey Bay in 1808, measuring eleven feet in length and weighing twenty-three stones. It pierced the bottom of the boat before it was secured. It has likewise occurred I believe at Scarborough and Whitby. A specimen of the Tunny (*Thynnus vulgaris*), seven or eight feet long, was stranded at Burlington a few years ago. Two examples of the Dory (*Zeus Faber*) were found on the beach at Redcar in 1839. The Opah (*Lampris guttatus*) is occasionally taken on the coast. One taken at Burlington two years since weighed four stones one pound, and was two feet ten inches long and one foot seven inches broad. The beautiful red scales of this species are extremely delicate and easily rubbed off, leaving the surface of a dull bluish slate colour.

The two species of gray Mullet (*Mugil Capito* and *Chelo*) are occasionally taken, as are most of the Gobioidæ. Of these, the One-spotted Goby (*G. unipunctatus* of Yarrell's Supplement) is abundant in the salt marshes at Redcar. The Ballan Wrasse (*Labrus maculatus*) appears occasionally in immense shoals off Filey, the largest weighing about five pounds. Four specimens only of Jago's Goldsinny (*Crenilabrus rupestris*) have been taken at Redcar. The Crucian Carp (*Cyprinus gibelio*) and the Gold Carp (*C. auratus*) are both plentiful in the reservoirs of some of our manufactories, the water being slightly heated by the admission of the waste steam from the engines. The former species is likewise common in some other ponds in the county. The Smelt (*Osmerus eperlanus*) is taken in various rivers, and was so abundant at Cawood on the Ouse in December 1834 as to be sold in the Leeds market at two pence the pound. The Atherine (*Atherina presbyter*) is taken at Burlington quay by persons when fishing with a worm; and the Argentine (*Scopelus Humboldtii*) was met with at Redcar in 1841, 1843 and 1844, from the 23rd of January to May, but never later. When first taken they have the smell of cucumbers. One specimen of Leach's Herring (*Clupea Leachii*) was found on the beach at Redcar in April 1843. The Common and Speckled Cod (*Morrhua vulgaris* and *punctata*) are common, and appear to be the same species, varying only according to the ground on which they feed. The Hake (*Merlucius vulgaris*) is a rare species with us. The Five-bearded Rockling (*Motella quinque-cirrata*) and the Lesser forked-beard (*Raniceps trifurcatus*) are both taken at Redcar. Several specimens of Muller's Top-knot (*Rhombus hirtus*) were found on the beach at Redcar in 1836, but none have occurred there since. The Smooth Sole (*R. arnoglossus*) and the Lemon Sole (*Solea pegusa*) are both taken, but rare. Several specimens of the Short Sun-fish (*Orthagoriscus Mola*) have been taken, one at Redcar, and two or three at Burlington. The Sharp-nosed Sturgeon (*Acipenser Sturio*) is occasionally taken off Redcar and in the Tees; and the Broad-nosed Sturgeon (*A. latirostris*) appears to be the species peculiar to the Ouse, the former not being taken in that river.

Of the Squalidæ or Shark family, the following appear the most remarkable species: the small and the large-spotted Dog (*Scyllium canicula* and *catulus*), the Blue Shark (*Carcharias glaucus*), taken off Scarborough; the Porbeagle (*Lamna Cornubica*), and the Beaumaris Shark (*L. Monensis*); the Common Tope (*Galeus vulgaris*); Smooth Hound (*Mustelus lævis*); the Basking Shark (*Selachus maximus*), and the Angel Fish (*Squatina Angelus*). A specimen of the Spinous Shark (*Echinorhinus spinosus*) was taken off Burlington in 1838, and an account of it was read at the Newcastle Meeting of the British Association by Arthur Strickland, Esq.

Of the Raiidæ, the most uncommon are the Shagreen Ray (*Raia chagrinea*), the Starry Ray (*Raia radiata*), the Sting Ray (*Trygon pastinaca*), and the Eagle Ray (*Myliobatis aquila*).

Of the Petromyzidæ, the Lamprey (*Petromyzon marinus*) is taken at Redcar and in the Tees; the Lampern (*Pet. fluviatilis*) in the Ure; the Fringed Lipped Lampern (*Pet. Planeri*) twice taken in twenty fathoms water off Redcar, and the Pride (*Ammocœtes branchialis*) in a small brook near Richmond. The extreme abundance of the Myxine or Hag (*Gastrobranchus cæcus*) may be imagined from the fact, that 123 specimens were taken out of one codfish at Redcar last winter.

Mr. T. West read a paper on the occurrence of Sclerotic Plates in Fishes. These plates had been noticed in birds, but not, that the author was aware, in fishes. They did not occur in all fishes, but the author suggested that they might be a provision to enable fishes to swim in rapid water.

Prof. Owen exhibited a human skull from South Australia, which had been used for the purpose of carrying water, in fact, as a widow's cruise. The absence of the art of pottery was the inducement for thus using this part of the human skeleton. The ancients, at their feasts, were said to quaff their wine from the skulls of their enemies, but he believed this was the first case in which it had been ascertained that any part of the human skeleton had been used as a domestic utensil.

Mr. Ball noticed the peculiar structure of the hoof of the Giraffe, which pre-eminently fits it for passing along mountain ravines with velocity. This structure consists in a brush-like structure of the sole of the foot.

Report of the Dredging Committee for 1844.

This report consisted of two parts: first, of the records of a series of dredging operations conducted round the coasts of Anglesea, in September 1844, by Mr. M'Andrew and Prof. E. Forbes, exhibiting the distribution of the marine animals procured in various depths down to thirty fathoms, and the state of the sea-bed in the localities explored. Among the more interesting facts recorded in these papers were the following:—rolled specimens of *Purpura lapillus*, a shell which lives only above low-water mark, were found in twenty-eight to thirty fathoms water on the gravelly bed of a line of current, at the distance of eight miles from the nearest shore. In the same line of current it was found that the few mollusca which lived there, such as Modiolæ and Limæ, had constructed nests, or protecting cases of pebbles, bound together by threads of byssus; and one species, the *Modiola discrepans*, had made its nest of the leaf-like expansions of *Flustra foliacea* cemented together. The attention of the dredgers was directed, among other subjects, to the distribution of Serpulæ, and the results of their researches were confirmatory of the statements recently advanced by Dr. Phillippi of Cassel, namely, that no dependence could be placed, even as to the genus, on the shell of a Serpula, perfectly similar shells being constructed by animals of different genera. Thus they found all the Serpulæ of a particular form in twelve fathoms water to be a species of Eupomatus, whilst exactly similar shells in twenty fathoms proved to be the habitations of a species of the genus wanting opercula, of which *S. tubularia* is the type. All the triangular Serpulæ they met with were *Pomatoceros tricuspis*. In twelve fathoms, at the entrance of the Menai Straits, they dredged the shell of *Helix aspersa*, the common snail, covered with barnacles and Serpulæ, and inhabited by a hermit crab.

Second, of a series of records of dredging operations conducted by Mr. Hyndman on the north coast of Ireland.

On some Animals new to the British Seas, discovered by Mr. M'Andrew.

By Prof. E. Forbes.

The additions to the British Fauna now brought forward were taken by Mr. M'Andrew on the western coast of Scotland. They are,—1st, a remarkable new zoophyte allied to *Virgularia*. This sea-pen is no less than two feet six inches in length, thus far exceeding in dimensions any British zoophytes of that genus, and differs also from all in having a perfectly quadrangular skeleton; it is the *Funicularia quadrangularis*. It was taken near Kerrera, in twenty fathoms water, on muddy ground, and is probably abundant there. 2nd. *Pleurotoma teres*, a shell of which only two specimens have hitherto been found, and those on the coast of Asia Minor. The British specimen is much larger than either of those taken in the Ægean by Prof. E. Forbes, and was dredged in forty fathoms water on mud. 3rd. *Eulima Macandræi*, a small but beautiful new species, differing from its British allies in the narrowness, flatness, and number (11) of the whorls, and in the angularity of its aperture. 4th. The *Emarginula crassa* of Sowerby, hitherto only known as a fossil, in which state it is found in the various crag deposits, and by Mr. Lyell in the Pleistocene of Norway. It is a most beautiful species, and the largest European member of the genus. Mr. M'Andrew dredged it alive in twenty-five fathoms in Loch Fine. It appears to have been also taken within the last year by Mr. Jeffreys and Mr. Alder. 5th. The singular radiate animal, which Müller figured in the 'Zoologia Danica' under the name of *Holothuria squamata*. Several other Mollusca and Radiata, probably new to the British Fauna, but as yet not sufficiently investigated, were also laid before the meeting by Mr. M'Andrew.

On Marine Zoology. By Charles William Peach.

The interesting annelid, the *Nereis tubicola* of Müller, was minutely described from specimens he had obtained alive from off the Cornish coast. He also noticed an annelid which is invariably found in the same shell with the *Pagurus bernhardus*, or Hermit Crab. This annelid varies in length from one inch to ten in length.

The nidus of a Doris had been met with in great numbers, and also the animal, in the spring of the present year; some he kept in sea-water in his house, which deposited their ova, and from which he succeeded in rearing the young. He minutely described them, showing that although in the adult state they are naked, they are clothed when young with a nautiloidal shelly covering. He also noticed that the young of the *Buccinum reticulatum* is found in a similar nautiloidal shell, with similar appendages and habits.

He introduced to notice a Holothuria with *twenty tentacula*, a link which had been long wanted in the history of this singular race. He described it as being not uncommon in deep water and rocky ground, and is sometimes a foot in length; it is called by the fishermen a "Nigger," and "Cotton Spinner," the former from its *dark* appearance, the latter from its thread-like bunches, which it ejects, and which become elongated into long and very fine tenacious threads, no doubt intended to annoy any enemy which might attack them, as they adhere firmly to anything they come into contact with. It is furnished with *four rows of suckers*, and covered with spine-like processes, and when the tentacula are withdrawn it has very much the appearance of a small cucumber. He minutely described the habits and peculiarities, proving satisfactorily that it is new to the British fauna.

He mentioned that Mr. Couch, Surgeon of Penzance, had found the *Boar Fish* in abundance, and the Plain Bonito not uncommon off the Land's End; also that a fine specimen of the *Maigre* had been lately captured off the Cornish coast, making the *second* within a short time.

He produced two new calcareous corallines, *Lepralia catenata* and *Lepralia pectinata*, which Dr. Johnston of Berwick-on-Tweed and Mr. Couch of Penzance have pronounced new and good species.

He exhibited a specimen of the *Cypræa moneta*, or Money Cowry, which had been trawled up off the Land's End with the animal in it.

Mr. Peach made a short communication on the Natural History of Goran in Cornwall.

On a New Genus of Nudibranchiate Mollusca.
By Professor ALLMAN, *M.R.I.A.*

Professor Allman noticed a new genus of Nudibranchiate Mollusca. The little animal upon which the new genus was founded, was obtained by Professor Allman in a salt-marsh on the south coast of Ireland, where it presented a singularly amphibious habit, several specimens being discovered creeping upon the leaves of *Enteromorpha intestinalis* and other plants quite beyond the reach of the water. The peculiarities of its structure are such as to approximate it to the genus *Venillia* of Messrs Alder and Hancock, with which it agrees in the median and dorsal termination of the intestine. The dorsal surface is furnished at each side with oval, rather irregularly disposed branchial papillæ. An examination of the mollusk in its living state was unfortunately neglected, and in the specimens preserved in spirits, Professor Allman, as well as Messrs Alder and Hancock, by whom they were examined, failed to detect any trace of tentacula. To the new genus the name ALDERIA was assigned, in honour of the distinguished naturalist to whom we are already so deeply indebted for our knowledge of the British Nudibranchiate Mollusca.

On a New Genus of Parasitic Arachnideans. By Professor ALLMAN.

On the Anatomy of Acteon viridis. *By* Professor ALLMAN.

The author controverted the assertions of M. de Quatrefages relative to numerous points in the anatomy of this little mollusk, and to the position assigned to it by the French naturalist in his new order *Phlebenterata*. Professor Allman described a distinct heart and vascular system, and a lateral termination of the intestine, points at direct variance with the statements of M. de Quatrefages. The *phlebenteric* system of this naturalist he maintained to be nothing more than a liver, to which organ it is in every respect analogous, and affords not the slightest grounds for considering it a distinct system peculiar to the Gasteropods included by M. de Quatrefages in his order *Phlebenterata*.

The nervous system was described in detail, and shown to be of a highly developed type. Seven ganglia, of which six are in pairs and one azygous, surround the œsophagus. The organs of vision and the bodies to which Siebold attributes an auditory function were described. The embryology of Acteon was traced, and it was shown that this mollusk underwent a metamorphosis quite similar to what has been observed in the Dorides and Aplysiæ, the larva being furnished with locomotive ciliated discs, and enclosed in a delicate nautiloid shell, where an operculum protects it from all external intrusion.

On a New Genus of Helianthoid Zoophytes. By Professor ALLMAN.

Professor Allman brought before the Section a Helianthoid zoophyte which he had just discovered at Cruick Haven, upon the southern coast of the county of Cork, and which, as far as he had as yet been able to determine, must probably constitute a new genus; he refrained, however, from naming it, in consequence of the limited number of works which he had had an opportunity of consulting since its discovery. The zoophyte is one of extreme beauty, and constitutes a connecting link between Actinia and Lucernaria, being distinguished from the former by its *capitate tentacula*, and from the latter by their arrangement in two *uninterrupted* series. Its anatomy closely corresponds with Actinia, but in the capitula with which the tentacula terminate, are to be found certain most singular organs. These consist of transparent oval capsules, having coiled up within them a very long fibre, which, under a high power of the microscope, is itself seen to be furnished with a spiral groove, with closely approximated coils, and traceable along its entire length. When the capsules are liberated from the tentacula, a most curious phænomenon is presented. The spiral fibre which they contain is forcibly ejected through one end of the capsule, and, uncoiling itself as it escapes, is rapidly shot across the stage of the microscope. Professor Allman insisted on the analogy between these bodies and the darts described by Corda in the tentacula of *Hydra fusca*, and was of opinion that they are organs gifted with the property of inflicting envenomed wounds upon the animals which constitute the food of the zoophyte. They are accompanied by other bodies whose structure appears to be that of a fibre rolled into a close spiral, but not furnished with a capsule.

On the Structure of the Lucernariæ. By Professor ALLMAN.

In this communication certain undescribed peculiarities in the anatomy of these zoophytes were laid before the Section, and the existence in the tentacula and other superficial parts of the animal, of organs analogous to the darts of Hydra, and to the spiral bodies of the Helianthoid zoophyte already described, was demonstrated. The position of the Lucernariæ in the animal kingdom is in close relation with the Acalephæ —a group with which they would appear to be more nearly allied than with the proper zoophytes, though they constitute a remarkable and beautiful transition between the Pulmonigrade Acalephæ on the one hand, and the Helianthoid zoophytes on the other.

Mr. Thompson read a paper entitled 'Additions to the Fauna of Ireland,' comprising a number of new species of Invertebrata, specimens of which were exhibited to the meeting. He called attention to the desirableness of the additions to the fauna and flora of Ireland and of Great Britain being brought forward regularly at the meetings of the Association, together with an exhibition of specimens of the respective species whenever practicable.

Mr. Thompson read 'Descriptions of *Pterochilus*, a new genus of Nudibranchiate Mollusca, and two new species of *Doris*,' by Joshua Alder and Albany Hancock. This communication was illustrated with splendid coloured drawings of the species executed by the authors, who likewise sent for exhibition drawings of the following four species described by them since the last meeting of the British Association, viz. *Proctonotus mucroniferus*, *Eolis alba*, *E. Farrani*, and *E. violacea*.

Dr. Carpenter communicated to the Section some observations on the position which he deemed ought to be given to the compound Ascidians in the zoological scale. In opposition to Milne Edwards, he considered that the compound Ascidians should be placed with the Mollusca, and the Ascidian Polyps with the Radiata.

On the Structure and Development of the Cystic Entozoa. *By* HARRY D. S. GOODSIR, *M.W.S., and Conservator Mus. R.C.S. Edinburgh.*

In this very natural order of Entozoa the author places the Acephalocysts, which were looked upon by Rudolphi and other helminthologists as being merely adventitious.

Three very distinct forms of the genus Acephalocystis were described; the specific characters being derived from the structure of the germinal membrane (the membrane from which the young originate), also from the mode of growth and structure of the young Hydatids.

In *Acephalocystis simplex* the membranes appear to be more or less inseparable, transparent, and the young vesicles are very few in number.

A. Monroi.—The germinal membrane of this species is divided, by means of a fibrous tissue, into numerous compartments, each of which are occupied by a delicate transparent vesicle filled with cellular substance, of which the cells or divisions are very large. Each of these vesicles contains one or more small dark bodies—the young Hydatids.

A. armatus.—The young arise from the germinal membrane of the parent as very distinct small separate vesicles, which at first are quite transparent, but soon become opake from the addition of young within them.

A small transparent vesicle jutting out from the surface of the germinal membrane is the first vestige of a young Hydatid, which speedily becomes opake in consequence of young cells growing within it. This very soon separates, and then becomes what the author terms a secondary Hydatid. The young cells which were seen growing within it before its separation now also increase in size, and soon become parent cells, but do not separate from the germinal membrane of their parent until she escapes from the primitive Hydatid. Thus there are four generations, the primitive Hydatid still containing the three generations to which she had given birth.

If the primitive Hydatid is buried so deeply in the tissues of the infested being as to prevent the escape of the secondary Hydatids with their two inclosed series of young, decomposition ensues, upon which they speedily disappear.

The author, after describing the very peculiar process of decomposition which takes place in these animals under such circumstances, proceeded to describe two very peculiar animals hitherto unobserved by naturalists, *Astoma acephalocystis* and *Diskostoma acephalocystis.* They were considered to be connecting links between the *Acephalic* and *Cephalic Entozoa,* and were the means of enabling the author to point out many beautiful analogies which existed between the Entozoa and the other classes of the animal kingdom.

The structure and habits of the genera Cænurus and Cysticercus were then described along with several new species, after which the author mentioned those Entozoa of the higher orders, such as the Nematoid, Cestoid, &c., which inhabit cysts. These species were not considered to belong to the Cystoid order of the class, but were merely brought forward by the author as illustrative of several views which he held relative to some points in the physiology of the Hydatids. He looked upon all these Entozoa, as Trichina, Gymnorhynchus, &c., as still inclosed within one or more of the membranes of the ovum, and that the inclosed animal received its nourishment by means of a peculiar structure in the inclosing membrane. If a small portion of the inclosing cyst of *Gymnorhynchus horridus* be placed under the microscope it will be found to consist of two membranes. The external consists of condensed cellular texture, and is derived from the tissues of the infested being; the internal membrane consists entirely of absorbing cells, through which the contained animal procures its nourishment. This is the general structure of all the cystoid Entozoa. Owing to the presence of a foreign body, the tissues of the infested being in the neighbourhood of the Entozoon throw out a quantity of lymph, which is always adding to the thickness of the external membrane of the cyst, until at length it becomes so thickened and hardened as to prevent the internal or absorbing membrane from procuring the requisite means of nourishment for the support of the inclosed animal, which, if stationary, very shortly dies, as in Acephalocystis. Gymnorhynchus, however, which has the power of motion, escapes this mode of extirpation, and when the cyst is examined, it presents the following appearances:—The cyst all around the head of the animal consists apparently of one, the absorbing membrane only, further back the external membrane becomes visible, and as portions are examined under the microscope, it is found to become thicker and thicker as it nears the posterior part of the cyst. The remains of this cyst can be traced for many feet in length in the tissues of the infested being, in the form of a delicate cord.

On the Reproduction of Lost Parts in the Crustacea.
By HARRY D. S. GOODSIR, *M.W.S.*

That all the species of Crustacea are endowed with the power of regenerating parts of their body which have been accidentally lost, is a fact which has been long known. The manner, however, in which these are developed, and the organ also from which the germ of the future leg is derived, has never yet been either properly explained or examined. If one or more of the distal phalanges of the leg of a common crab be torn forcibly off, the animal instantly throws off the remaining parts of the limb. This is effected with little apparent exertion, and always takes place at one spot, which is marked externally by a delicate line covered with an annulus of thinly-scattered hairs. The phalanx on either side of this ring is considerably contracted, and when the shell is taken carefully off so as to expose the interior, it is found to consist of a fibrous, gelatinous, glandular-looking mass—the organ which supplies the germs for future limbs.

The microscopic structure of this organ is extremely beautiful. When a thin transverse section is made and placed under the microscope, it is found to present the following appearance :—1st, a foramen near to one edge for the transmission of the vessels and nerves ; then a semiliquid mass containing small nucleated cells, which is surrounded by a fibrous-looking band ; beyond this band lies a mass of blastema of large nucleated cells ; and lastly, the shell membrane covered by the shell incloses the whole.

The fibrous-looking band here mentioned is found from further observations to belong to a very peculiar system of vessels very generally distributed throughout the body, and which all terminate by means of shut sacs, on each of which a dark circular spot is observed, having all the appearance of a germinal disc. The author, from want of time, has not been yet able to make out the relations of these vessels.

Some hours after the limb is thrown off, the small foramen becomes gradually filled by a small rounded body (the germ of the future leg), which gradually increases in size so as to push out before it the cicatrix which had been formed on the raw surface after the injury, and now forms the external covering of the young limb. As the germ increases in size, the inclosing membranes become thinner and thinner until they burst, when the young limb, which has hitherto been bent upon itself, becomes extended, and has all the appearance of a perfect limb except in size. As far as the observations of the author had gone, it appeared that the germ was derived from one of the cells nearest the foramen. This cell follows the ordinary course of development, by the nucleus breaking up into nucleoli which in time become parent cells also, each of which undergoes the same process. This goes on for several stages, all the less important cells dissolving and serving as nourishment to the central or more important ones, until the number of centres are reduced to five—the number of joints required, which, by a regular process of a similar nature, assume the form of the future leg.

On the Morphology of the Reproductive System of Sertularian Zoophytes, and its Analogy with that of Flowering Plants. By Prof. E. FORBES.

At certain periods in the life of the sertularian zoophytes, which are composite beings of plant-like forms, constituted of numerous *nutritive* individuals which, besides the life of each share in the common life of the whole, there appear on the axis or branches variously formed bodies, in some species urn-shaped, in others pod-shaped, very dissimilar from the other parts of the whole, in which, after a time, the ova are formed. These are the ovigerous vesicles of naturalists, the true nature of which has been often discussed, but hitherto unexplained. These bodies, Prof. E. Forbes maintains, are branches of many individuals which have undergone an *ideal* metamorphosis, exactly comparable to that which Linnæus first, and Goethe afterwards, demonstrated in the flowers of vegetables. He states his theory of their nature thus :—The vesicle is formed from a branch or pinna, through an arrest of individual development, by a shortening of the spiral axis, and by a transformation of the stomachs (individuals) into egg-producing membranes, the dermato-skeletons (or cells) uniting to form the protecting capsule or germen; which metamorphosis is exactly comparable to that which we find in the reproductive organs of flowering plants in which the floral bud (normally a branch clothed with spirally arranged leaves, an assemblage of respiratory individuals) is constituted through the contraction of the axis and the whorling of the individuals borne on that axis, and by their transformation into the several parts of the flower. In order to prove this theory, the author submits the several forms of ovigerous vesicle in the family of Sertulariadæ to a searching analysis, taking the pod-like vesicle of most Plumulariæ, usually regarded as the most complex, but in reality the simplest, as a type. He shows that all the classes of forms, six in number, may be explained by means of his proposed view of their nature, which is further borne out by certain monstrosities which have occasionally occurred among the zoophytes. Having, as he conceives, proved his position, he proceeds to show its application to systematic zoophytology, urging the dismemberment of the genera *Sertularia* and *Plumularia*, the separation of the Sertulariadæ from the Hydraidæ and Tubulariadæ, as an order equal in value to these families united, and the arrangement of the zoophytes under four orders, of which the above-named families form two, and the Helianthoid and Asteroid polypes the other two, the Bryozoa being transferred to the Mollusca, where they should form a family parallel and equal to the compound Tunicata.

On the Organs of Generation in the Decapodous Crustacea.
By Harry D. S. Goodsir, *M.W.S.*

The internal organs are more highly developed in the Brachyura than in any other section of the class, and the genus Hyas was selected from it by the author as most fitted for illustrating the general anatomy of these organs.

On the Conservation of Substances. *By* A. Goadby.

Mr. Goadby exhibited a series of preparations of animal bodies preserved in glass cases, according to a method of his own suggestion. Many gentlemen having complained that they had not succeeded in preparing animal substances in the way which he had recommended, he was desirous of stating fully the plans which he pursued. The following were the formulæ for all the solutions he used :—

A 1.	
Bay salt	4 oz.
Alum	2 „
Corrosive sublimate	2 grains.
Water	1 quart.

A 2.	
Bay salt	4 oz.
Alum	2 „
Corrosive sublimate	4 grains.
Water	2 quarts.

B.	
Bay salt	½ lb.
Corrosive sublimate	2 grains.
Water	1 quart.

BB.	
Bay salt	½ lb.
Arsenious acid (or white oxide of arsenic)	20 grains.
Boiling water	1 quart.

C.	
Bay salt	½ lb.
Arsenious acid	20 grains.
Corrosive sublimate	2 grains.
Boiling water	1 quart.

The first, A 1, was the ordinary solution he used: A 2, where there was a tendency to mouldiness, and the animal texture was tender, as, although salt preserved animal matters, it sometimes destroyed the tissue. B. was used in cases where animals contained carbonate of lime, as, in these cases, alum produced decomposition. For old preparations, arsenic was substituted for corrosive sublimate, as in BB., but where there was a tendency to too much softening, the corrosive sublimate should be added, as in C.

Suggestions for the Observation of Periodic Changes in Animals. *By* THOMAS LAYCOCK, *M.D.*

At a previous Meeting of the Association the author communicated to the Medical Section a paper on a general law governing the recurrence of vital phænomena. In illustration of the subject he traced the connexion between the periods of development in various races of the animal kingdom, and those of man as seen in the paroxysms of nervous affection, and particularly of fevers. In the present paper he directs the special attention of naturalists to those changes in animals the periods of which can be best measured, and concerning which a large amount of important and accurate observations can be obtained. The epochs of development and metamorphosis, and the periods passed in incubation, are specially cited as meriting accurate and extensive observation, and the author concludes by quoting the system of registration already established in Belgium as deserving imitation and cooperation.

On the Flora of Yorkshire. *By* O. A. MOORE.

He commenced by expressing his regret, that owing to the shortness of the time allowed for its completion, the memoirs might appear not quite so perfect in some respects as it otherwise might have been, especially as regards species peculiar to the sea-coast; all plants, too, were excluded from the list not strictly found on the Yorkshire side of the Tees in Teesdale. In this list were included 1119 species and 157 varieties (many of which latter are considered species by some botanists), exclusive of a few whose claims to be regarded as Yorkshire plants rest on insufficient grounds. The list might be regarded as an appendix to the work of Mr. Baines which appeared four years previously, and which contains an accurate and extensive list of habitats for all the principal flowering plants and ferns of Yorkshire, as well as the Mosses and Characeæ. In the present report the subsequent labours of botanists had been noticed, and about 87 species and 81 varieties were mentioned, which had not previously appeared in any general list. Additional localities were given for some of the rarer species, when only two or three had been previously recorded; and the names of those botanists were mentioned through whose assistance much valuable information on the flowering plants and ferns of Yorkshire was obtained, to which two families the list was confined. They were distributed into the following classes: *Exogens*—species 808, varieties 101; *Endogens*—species 262, varieties 35; *Acrogens*—species 49, varieties 21. To this was appended an analysis of the species and varieties in natural orders.

The list, which was of considerable length, was then gone through in a cursory manner, the time only permitting the leading points to be alluded to; and remarks were made on such species as were either very rare or had some peculiarity in their habit or mode of growth. The following were a few of the principal additions mentioned in the list:—*Anemone apennina, Barbarea stricta*; this species was shown to be common in many parts of the county, especially on the banks of the Don at Doncaster, at York, Smeaton, &c. &c.; its claims to be regarded as a distinct species were also pointed out. *Camelina dentata, Alyssum calycinum, Lepidium Smithii, Dianthus plumarius, D. deltoides*, var. *glaucus, Silene anglica, Hypericum perforatum β, H. maculatum, Vicia orobus, Alchemilla alpina, Rosa involuta, Epilobium virgatum, Callitriche platycarpa, C. pedunculata β, Sedum rupestre, Saxifraga geum, Asperula arvensis, Valerianella auricula, Solidago virgaurea β, Artemisia campestris, Crepis succisæfolia, Hieracium diaphanum α, H. Lapeyrousii, H. prenanthoides, H. rigidum α β, H. boreale, Cuscuta trifolii, Orobanche rubra*. This plant was found at Leyburn Shaw by the Rev. — Pulleine, and is another instance of the species not being confined to the basalt. *Scrophularia Ehrharti, Melampyrum pratense β, Veronica triphyllos, V. Buxbaumii, Mimulus luteus, Mentha aquatica β, citrata, M. pulegium, Stachys palustris*, var. *β ambigua, Primula farinosa*, var. *pumila*. This curious dwarf variety from Hanxwell Moor was exhibited. *Chenopodium olidum, C. ficifolium, C. murale, Atriplex littoralis, A. erecta, A. deltoidea, Halimus portulacoides, Rumex palustris, R. pratensis, R. aquaticus*. This plant was shown to be the common roadside dock at Hawes, Wensleydale, and grew on dry stone quarries, &c. *Polygonum mite, Salix rugosa, tenuifolia, Weigelliana, Aceras anthropophora, Habenaria chlorantha, Juncus maritimus, cænosus, obtusifolius, Potamogeton oblongus, plantagineus, Carex paradoxa,* *rigida, Eleocharis acicularis*, var. *elongata, Calamagrostis pyramidalis, Bromus patulus, commutatus, Cynosurus echinatus, Avena pratensis β alpina, Lolium multiflorum, Equisetum Drummondii, Isoetes lacustris, Onoclea sensibilis.*

Description of Alexandria Imperatricis, *a new Genus of Papilionaceæ.* *By the* Chevalier SCHOMBURGK.

This tree, in appearance, is one of the most beautiful and gorgeous of the family of Leguminosæ, and was discovered by the author at the foot of the northern ridge of sandstone mountains in the pluvial basin of the River Cuyuni, in Guiana, and reaches a height of from 100 to 120 feet. The flowers are developed directly from the trunk and woody branches, in large clusters, and the racemes, pedicles, and calyces are of a rich crimson, the petals bright orange, striped with crimson, the vexillum of a deep purple, and ascending. The pod is from eighteen to twenty inches long, and contains several seeds.

On a new Species of Barbacenia. *By the* Chevalier SCHOMBURGK.

This plant grows on the table land from which Mount Roraima rises. It reaches frequently a height of ten or twelve feet, branching in a dichotomous manner, and bears a number of flowers, which in their appearance are liliaceous, and five to six inches long. They are, outside, of a delicately purplish hue, and deliciously fragrant. It differs from the species of hitherto described Barbaceniæ, in possessing eighteen fertile stamens. The difference in the number of stamens is not, however, allowed to be generic in allied species of Velloziæ, and, therefore, the author has placed this plant with the Barbaceniæ.

On the Ophiocaryon Paradoxa, *the Snake-nut Tree.* *By the* Chevalier SCHOMBURGK.

In a former communication Mr. Schomburgk had called the attention of naturalists to the peculiar seed of this tree. The seed is covered over with a membrane, which, on being removed, presents the embryo elongated and twisted in a spiral manner, so as to give it the form of a snake. From a recent examination of the flowers of this tree, the author had found that it belonged to the natural order Sapindaceæ. The embryo is twisted in other members of this order.

On the Calycophyllum Stanleyanum. *By the* Chevalier SCHOMBURGK.

There are several genera of the natural family of Rubiaceæ, as Calycophyllum, Mussænda, Pinkneya, &c., where one of the teeth of the calyx expands into a coloured petioled leaf, of a membranaceous texture. In this tree it is very remarkable; and as these bractlike organs are of a rose colour, they give a very beautiful aspect to the forest where they grow. This appendage only grows after the flower has dropped off, and developes itself with astonishing rapidity. The tree grows on the banks of the rivers Rupununi and Takutu, in the third parallel of north latitude.

Description of Lightia lemniscata, *a new Genus of the Family Buttneriaceæ.* *By the* Chevalier SCHOMBURGK.

The Buttneriaceæ are very common in Guiana, and in some districts the author met with whole forests of the chocolate nut tree, a plant belonging to this family. The Lightia belongs to this family. The great peculiarity of the plant is, that the petals have an elongated appendage, which hangs down from the cluster of flowers like ribbons, and hence its specific name. This tree attains a height of twenty or twenty-four feet, and produces its flowers directly from the stem, below the axis of fallen leaves. Only three specimens of this tree were discovered in Guiana by Mr. Schomburgk.

On two New Species of the Family Laurineæ, from the Forests of Guiana. By the Chevalier Schomburgk.

The first is a tree which affords timber which is brought to England, and known by the name of Greenheart. This tree was found, by Dr. Bodie, to possess febrifugal properties, and Dr. Maclagan has published an account of two new alkaloids which he had obtained from it by chemical processes. These alkaloids may be used instead of quinine. The second tree has long been known, and yields an aromatic fruit, known by the name of the Accawai nutmeg, and is extensively used in Guiana as a remedy in diarrhœa, dysentery, and other intestinal diseases. The author succeeded in obtaining flowers and seeds, and had found this tree to be a species of Acrodiclidium, to which he has given the specific name Camara. It appears to be restricted to the sandstone mountains of Roraima, between the fifth and sixth parallel of north latitude.

Mr. Schomburgk exhibited dried specimens and drawings of most of the plants he described, as also of the *Strychnos toxifera*, a plant which produces the true Wouraii poison of Guiana.

The Chevalier Schomburgk read a paper on the Forest Trees of British Guiana, and their use in civil and naval architecture. This paper was illustrated by a great number of polished specimens, and some of them possessed extraordinary beauty of marking. The author also exhibited a specimen of the trunk of the *Aspidosperma excelsum*, which grows in the form of a fluted column; and drew attention to the nest of the Rock Manakin, or Cock of the Rock (*Rupicola elegans*); and to the head of the largest freshwater fish known, the *Sudis gigas* of Cuvier, both of which he had brought from Guiana.

On some Peculiarities in the Flight of Birds, especially as that is influenced in some Species by the power they possess of decreasing and adjusting their own specific gravity. By Thomas Allis.

Birds require the centre of gravity to be placed immediately over the axis of motion for walking, and beneath it when flying; when suspended in the air their bodies naturally fall into that position which throws the centre of gravity beneath the wings. The axis of motion being situated in a different place in the line of the body when walking from that which is used when flying, the discrepancy requires to be compensated by some means in all birds, in order to enable them to perform flight with ease. Raptorial birds take a horizontal position when suspended in the air, and the compensating power consists in their taking a more or less erect position when at rest. Another class, including the woodpeckers, wagtails, &c., take an oblique position in the air; with these the compensating power consists in their cleaving and passing through the air at an angle coincident with the position of the body, and performing flight by a series of curves or saltations.

Natatorial birds sometimes need very extended flight; they take a very oblique position in the air; they have the ribs greatly lengthened, the integuments of the abdomen are long and flexible, which enables them greatly to enlarge the abdominal portion of their bodies by inflating it with air; this causes a decrease in the specific gravity of that part and raises it to a horizontal position; the compensating power consists in the posterior half of the body becoming specifically lighter, while the specific gravity of the anterior half remains unaltered.

Mr. Babington exhibited to the Section specimens of three plants which had been added to the list of British plants during the summer of 1844.

1. *Alsine stricta*, discovered on Widdy-bank Fell in Teesdale, Durham, by Mr. James Backhouse of York and a small party of botanists. It occurred in small quantity, but from the nature of the locality and the plant inhabiting the northern parts of Europe, it must be considered as an aboriginal native of England.

2. *Carduus setosus*, growing near the shore of the Frith of Forth in the neighbourhood of Culross. As it is a native of the countries to the north-west of the Black

Sea, there is every reason to believe that it has been introduced from that region to Scotland by accident. It has now taken firm hold at Culross, where it was detected by Dr. Dewar of Dunfermline.

3. *Galium Vaillantii.* This plant has often, and perhaps justly, been considered as a variety of the common *G. Aparine*, with which it connects the Linnæan *G. spurium.* It has occurred to Mr. G. S. Gibson of Saffron Walden, Essex, in cultivated fields near to that town.

On the Cultivation of the Silk Worm. By Mrs. Whitby.

Extract of a Letter to the Assistant General Secretary.

Newlands, Lymington, Hants,
August 8, 1844.

Sir,—Having observed in those parts of Italy where the finest silk is grown, viz. in Lombardy and Piedmont, that the winter is equally rigorous with that of England (nay, the frosts are more severe and of longer continuance), and having ascertained that the silk worm is "educated" in rooms where ventilators are even more requisite than stoves, thus proving to me that climate was no bar, I determined to make the experiment whether the culture of silk could not be made the means of giving bread to some of our unemployed poor women and children. I was not deterred by learning that a similar experiment had already been made by a Company conjointly in England and Ireland, because there is a vast difference between a company and the efforts of an individual determined to ascertain by actual personal superintendence the probability of success.

I have cultivated with great success the white mulberry of the Philippine Isles, or *Morus multicaulis*, and have a flourishing field which has fed thousands of silk-worms this year and several preceding ones; and I have in proof several pounds weight of well-wound silk, equal to any that can be imported from France or Italy.

On the Cultivation of Ferns. By T. Allis.

In the cultivation of Ferns I find many that are of constant character; they may be more or less vigorous, but the characters remain unaltered, and the eye at once recognises them; others, again, are subject to considerable alteration, as in some of the Adiantæ. *A. affine* has usually only three digits, but I have plants in a vigorous state of growth with the number of digits increased, and quite undistinguishable from the allied species *A. pubescens*: in Newman's 'British Ferns' *Polypodium Dryopteris* and *P. calcareum* are considered as one; with me they retain their distinct characters under all circumstances of growth: I have grown them in peat beds within a few feet of each other: there *P. calcareum* retains its peculiar hue from the first appearance of the frond above ground, its greener and more chaffy stem, and its more rigid appearance; and I always find that it sends up fewer fronds than *P. Dryopteris*, which are almost always fertile: these distinctions have been retained growing in a peat-bed, in common garden soil, in pots in the house, and when raised from seed. As a general rule, though liable to exceptions, I find that plants which have other means of propagation than from seed, fructify less freely than those which grow by an extension of the rhizoma, or which propagate themselves by sending out young plants at the extremity of the frond, as is the case with *Asplenium flabellifolium*, Danaeæ and *Asplenium Rhizophyllum*, which generate a young plant near the under extremity of the frond, as *Woodwardia radicans*, or which have young plants sprouting from the upper surface of the frond, as is the case with *Asplenium viviparum*; on the other hand, *Aspidium bulbiferum* is an exception to this rule: this plant bears an ample crop of little bulbs, which fall off and germinate freely like the little black tubers from the tiger lily, while at the same time the frond is covered on the under side with sporules. *Asplenium viviparum* and *Woodwardia radicans* have never fructified in my possession. Another instance occurs in *Aspidium Thelypteris*. We have one locality in this neighbourhood where it grows under wood in an open peaty soil, and where we may find it scattered over acres and scarcely find a single fertile frond; in another locality, where the rhizoma has not so free a range, it fructifies freely, and in my own garden, in a stiff soil, almost every frond is fertile, while in a peat-bed about three yards off almost every frond is sterile: I know not whether botanists (a name to which I have no pretension, though offering a paper in the Botanical Section) would expect to find crosses or new varieties spring up from seed in a class of plants which have no recognisable organs of generation; but we find it so in practice. I possess a species of Gymnogramma which was obtained from seed by J. S. Henderson, gardener to Earl Fitzwilliam at Milton: it is different from any previously cultivated species. I also have a plant of my own which appears to be (and I have no doubt is) a Pteris, unlike any plant I before possessed, or that I recollect to have seen; from its appearance I should take it to be a cross between *Pteris* —— and *P. flexuosa*, but unfortunately the latter beautiful plant has never fructified with me. I find a great difference in the frequency with which the ferns propagate themselves spontaneously from seed: the genus Pteris is among the most frequent, and springs up of various species in all directions: Blechnum, Doodia and Gymnogramma also spring up freely, as do some species of Diplazium; Cheilanthes and Dicksonia frequently occur: of Polypodiums I have had very few seedlings; the same may be said of exotic Aspidiums, and only a few Aspleniums. I have this year adopted what I believe to be a new method in raising ferns from seed, and, as far as I can at present judge, with complete success: the plan I have adopted is to obtain a block of peat turf, such as is sold in York for the purpose of lighting fires; that I thoroughly soak in water, and then place in a cucumber frame; then I sow the seed, and keeping them shaded from the sun, I have a good crop of plants; but I am yet unable to determine whether they will prove to be the species sown, three of which have not before been, as I believe, cultivated in England; the species are *Polypodium membranifolium*, *Asplenium variifolium* and *Alsophila* ——, all from Norfolk Island.

The seed of ferns is so volatile and so fills the air, that though I have used a good deal of care to prevent seed from finding its way to my seed-beds, I am as yet unable to assure myself of possessing the new species. In the work on Australia from the pen of my friend and relative James Backhouse, there is a notice of the occurrence of many species of Ferns; and from his observations on the native habits and habitats of several species I have derived great advantage, especially so by planting a considerable number on decayed trunks of trees, where they grow with a vigour such as I never before experienced: a particular instance is the beautiful *Asplenium Nidus*, a plant I have had for years, but which was always in so feeble a state that it was scarcely able to maintain existence; and I had sent it out to nurse, under the care of our experienced curator, in the orchideous stove in the Museum Gardens; still it never put on a healthy appearance till planted in part of the stump of our old willow, where it now flourishes in the greatest vigour, and is putting forth its fertile fronds.

Further Experiments and Observations on the Argonauta Argo. *By* Madame JEANETTE POWER. *Communicated by* Professor OWEN, *F.R.S.*

Prof. Owen communicated two memoirs which he had received from Madame Jeanette Power on the Paper Nautilus (*Argonauta Argo*). He premised some brief observations on the uncertainty which had prevailed from the time of Aristotle to that of Cuvier, as to the real nature of the molluscous fabricator of the Argonaut shell, and alluded to the opinion entertained by many conchologists to within the last six or eight years, that the Cephalopod usually found in the Argonaut shell was a parasitic occupant. The thin expanded membranes which characterize one pair of the arms of this Cephalopod, had usually been described, up to the same period, as the sails by which the Argonaut was wafted along the surface of the sea, whilst the six long and slender arms were supposed to serve as oars, extending from the sides of the boat; and the little navigator, thus fancifully depicted, had been a favourite subject of imagery in the song of the poet, from Callimachus to Byron.

Madame Power, during a residence in Sicily in 1833 and 1834, had made observations on the numerous specimens of the *Argonauta Argo*, confined in submarine cages at Messina, tending to prove that the Cephalopod inhabiting that shell was its true constructor, and that the supposed sails were the organs concerned in the formation and repair of the shell. These observations were communicated by Madame

Power to the Giænian Academy of Catania, and are published, with Reports on them by Profs. di Giacomo, Gemellaro and Maravigna, in the Transactions of the Academy, vol. ix., and in the Journal of the Giænian Literary Society for December 1834; in the journal entitled 'Passe temps pour les Dames,' fifth year, No. 1; and in the 'Effemerido Scientifico e Letterario per la Sicilia,' No. lxv. The principal results of these observations, with a series of specimens of the young Argonauta, were submitted by Madame Power to the Zoological Society of London in 1837, and gave rise to discussions which are detailed in the Proceedings of the Society for 1837, and are more briefly summed up in the second volume of the Zoological Transactions, pp. 114, 115. (See Athenæum, No. 590.) But as the evidence adduced by Madame Power was deemed by some naturalists to be inconclusive against the parasitism of the Cephalopod inhabiting the Argonaut, Prof. Owen had suggested to Madame Power the experiment of cutting off one of the membranous arms in a living Argonaut, and preserving the mutilated Cephalopod alive as long as possible, to observe the effect of the operation on the growth or repair of the shell.

Madame Power revisited Sicily in 1838, and transmitted to Prof. Owen, in 1840, a letter descriptive of her 'Experiments and Observations upon the *Argonauta Argo*, made during the months of October, November and December, 1839;' and Prof. Owen, having recently received from Madame Power the specimens of the Argonaut experimented on, which satisfactorily confirm the accuracy of the account of the experiments and conclusions in that letter, proceeded to communicate the following translation of it to the Zoological Section of the Association:—

"HONOURED FRIEND.—In fulfilment of the gratifying charge you imposed upon me, I present you with my slight work. It contains exactly the result of the observations which you, with so much judgement, proposed to me. I am aware that I ought to have withdrawn from the task, not possessing sufficient scientific knowledge for the undertaking, but the hope of kind indulgence encouraged me to proceed.

"October 15th.—I placed my cages in the port of Messina, putting into them several Argonauts, which had plenty of eggs suspended under the apex of the spire of the shell, of which I measured the respective sizes. In order to ascertain what was their favourite food, I gave them, in small pieces, Venuses, Crustacea, fish, flesh, and a whole calamajo (*Loligo sagittata*, Lamarck), which is very common in the Messina channel. They no sooner saw this last eatable, than they threw themselves upon it, and it was curious to behold with what avidity they dragged it, now to the right, now to the left, putting all their powers in action, and disputing among themselves for victory and possession.

"October 16th.—Having procured two more Argonautæ, I cut from one of them the right membranous arm, and from the other the left; breaking off a piece from the side of the shell of each corresponding with the cut arm. I then placed the Argonauts in a cage*. The first died the day after, and the other five days after, and, in this, I observed that the right portion of the shell exceeded, by about a line and a half, that of the left, where the arm had been cut off. [This is shown in specimen No. 1.—R. O.] This convinced me that the animal, not having the left arm entire, could not in consequence increase the shell on that side, while it proceeded in doing so on the right side. I made several other trials, but without success, as all the animals died, if not immediately, within a few hours after their being cut.

"In order to succeed in my undertaking, I thought of breaking a piece off the extremity of the great whorl" (giro), "and performed this on six shells of the Argonaut, to see whether the Cephalopod, after having repaired them, would proceed in augmenting them. In four, six and ten days the Cephalopods not only repaired them, but proceeded to enlarge them, as the specimens Nos. 2 to 3 show. This is one of the reasons which go to prove that the Cephalopod is the real fabricator of its own shell, and confirms the statement made in my first memoirs.

"October 28th.—I cut from four Cephalopods of the Argonaut about the half of the membranous arms; in two of them, cutting that on the right side, in the others, that on the left, and I broke pieces, corresponding with the middle of the arm, out of the shells. Two days afterwards I found them dead; two only of them had repaired, and but imperfectly, their shell; one on the left side (No. 5) and the other on the

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* "It is necessary to perform this operation in sea water of the same temperature as its ordinary warmth, for if it be cold it kills the Argonauts."

right (No. 6). This clearly shows they must have been much hurt. In the inside of the shell No. 5, it may be observed, that the poulp repaired its shell with two little morsels of the same, which, in cutting it, I left within. The poulp is very clever, but with all its ingenuity could not succeed in properly placing the bits, as this specimen shows.

"October 29th.—I broke from a shell a piece of the length of eleven lines, exactly where the dark spots are situated on the keel of the Argonaut, to ascertain whether in repairing it the spots would be reproduced. The shell was no sooner broken than the poulp spread its membranes over it, and in this manner swam about, ate, and did not uncover its shell till the reparation was completed. Three hours after the breaking I took up the Argonaut with my net, and the keel was mended with a fine skin, on which the rudiments of the spots were visible. (See specimen, No. 7.) This experiment proves clearly that the reparation is effected by transudation from the membranous arms of the Cephalopod."

The letter then proceeds to detail observations on the different rate of growth of the young Argonauts which are excluded from the egg whilst within the cavity of the spire of the parent shell, where they are protected for a time, as in a marsupial pouch, and the escape of the young at successive intervals from that nursery. "To ascertain whether the young Argonauts after exclusion from the egg could live without the aid of the parent, I made the following experiments:—I took a number of them which had been born two days before and put them into a large glass vessel filled with sea-water and covered with muslin, through which the water could have ingress and egress without allowing the young Argonauts to escape; I put the vase into a basket, to which I suspended a piece of iron to make it fall to the bottom of the cage. The next day they were all dead. I repeated the experiment, detailed in my first memoir*, to ascertain whether the ova could be developed without the aid of the parent; it was on the same plan as the preceding with regard to the small polypes. In twenty-four hours after removal from the spire of the parent shell the eggs had enlarged to double the size they were when put into the vase, and in eight days no vestige of them remained; they had evidently decayed and been dissolved. I doubt not, therefore, that the parent Argonaut attends to the preservation and development of the eggs within the spire, and preserves them with some gelatinous or mucilaginous matter from the contact of the sea-water." Madame Power then states that having examined at least 600 specimens of the Argonaut in the course of her inquiries, she had not once discovered a male specimen, but that all had eggs adhering in greater or less quantity to the involuted spire of the shell: the accomplished naturalist concludes by observing, "From this great quantity of Argonauts, from very young specimens to those of full size, you may see that I have endeavoured to omit nothing that could elucidate those interesting points noted by you. I am sorry that this year, in consequence of the bad weather, I am not able to put before you the young Argonauts developed as far as the beginning of the fabrication of their shells: I hope in future to be more fortunate. I must also add, that having several times wished to repeat my observations on the fate of the Cephalopod of the Argonaut, when taken out of its shell, the result has been that they sometimes, with difficulty, replace themselves in the shell, but that, if the shell be removed, they do not form another, but die in consequence. And I assure you that the Cephalopod of the Argonaut is the most difficult of marine animals to study from its extreme delicacy, and that out of 100 experimented on, not more than fifteen survived. It now only remains to me to render you most sincere thanks, and to profess myself most grateful for your instructions and for the pleasure you have given me in satisfying in any degree your wishes.

(Signed) "JEANETTE POWER."

"Messina, 30th January, 1840."

The second Memoir, entitled 'Continuation of Observations on the Polypus of the *Argonauta Argo*, in 1839,' contains a more detailed account of the experiments recounted in the foregoing letter, with additional observations. The relative position of the animal to its shell is always the same: when retracted the visceral sac is lodged in the spire, the membranous arms to the right and left, the other six arms placed beneath the body in the middle; the mouth in the centre of the large aperture

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* Trans. Acad. Giænian, vol. ix. 1824.

of the shell, the eyes being visible on the right and left through the sub-transparent shell; the siphon resting upon the open part of the keel about two lines from its extremity. Wishing to ascertain whether the animal thus situated could see, Madame Power gently pushed towards it a small stick, and although at a distance of four feet from the eye, it at once ceased swimming, and sank to the bottom. The animal swims by the reaction of the respiratory currents forcibly ejected from the siphon, which, by its various movements, guides the progress of the Argonaut. When the animal is in the act of enlarging its shell, it spreads the two membranous arms or mantles over the sides of the shell, fixing the suckers at the margin of the arm upon the points at the sides of the keel. "At first the mantle appears like silver; then gently moving in its shell the animal produces a change of scene, and there appears upon the silvery ground beautiful marks like golden rings with black points in the centre of them. When the animal is irritated, the colour changes to a deep red, and then to dark violet, and when in this state it dies.

"The body of the young Argonaut fills the shell completely, and when swimming, it shows the siphon: as the period of reproduction approaches it enlarges the shell very much, the aperture exceeding the body by one or two inches; and thus, when swimming, the siphon is not visible: when the cavity of the spire is filled with eggs or young Argonauts, the parent places its body more forward, and its siphon reappears when swimming." With regard to the locomotion of the Argonaut, Madame Power observes, that "It would be difficult to describe the immense variety of the movements of the *Argonauta Argo* in swimming, dragging and floating, and it would require a series of drawings to represent them: these movements vary according to the fancy or caprice of the animal, or to circumstances; for instance, when at the bottom of the water, and wishing to rise or go in any other direction, the only movement it makes is to agitate its siphon, and thus it swims with its body and eight arms hidden in the shell; or it swims with its mantles totally or in part extended over the shell; or holding a portion of the body more or less above the shell; or holding its prey with its arms. The Argonaut also drags itself along the sand, gravel or mud at the bottom, or climbs millepores and madrepores in search of molluscs or other nutriment, or when it seeks concealment; it sometimes anchors by its lower arms, hanging from the shell and attached by their suckers." The various movements of the Argonaut are then described as observed during its partial protrusion from and retraction into the shell, whilst putting out or retiring its mantles within the shell; whilst turning over, or turning to the right or the left; when floating on the water; when attacking its foes, or defending itself from them; and when throwing water and ink into the faces of any persons who try to take them, or when otherwise irritated.

Madame Power alludes to her having transmitted, through the Chevalier Alban de Gasquet, Lieutenant de Vaisseau, who was at Messina at the commencement of 1835, and by his request, to his friend M. Sander Rang, Officier Supérieur au Corps Royale de la Marine, an account of her observations and experiments on the *Argonauta Argo*, made in the years 1833 and 1834, and which are noticed by M. Rang in his Memoir on the Argonauta, published in 1837; and the memoir concludes by a letter addressed by Mr. G. B. Sowerby to Madame Power, acquainting her that he possessed a specimen of the shell of the *Argonauta tuberculosa* which had been broken and repaired in a manner which proved the correctness of her observations.

The second memoir was illustrated with three beautiful drawings of the *Argonauta Argo* in different positions, and with the membranous arms expanded upon the shell, in different states of retraction, and wholly retracted.

The skull of an Aboriginal of South Australia, transmitted by Governor Grey as an example of the habit of the tribe to convert that part of the human body into a vessel for holding and carrying water, was exhibited by Professor Owen. He explained the mode in which it had been made applicable to this purpose. After removal of the soft parts of the head and the lower jaw, the bones of the face had been broken away, with the partition and roof of the orbits, and the cranial box was then suspended by a neatly plaited net-rope of threads, made of twisted vegetable fibres, passed through the hole made in the roof of the orbits and through the foramen magnum, this suspender being terminated by an ornamental tassel. Leakage by the sutures of the cranium, especially the squamous suture, had been prevented by pitching them over with a native bitumen and cementing pieces of the nacreous lining of shells along the course of the sutures.

The exterior of this specimen of barbarous art was polished, and the processes and other protuberances worn smooth by habitual use: the effects of this were most obvious on the external angular processes of the orbits, which seemed to have served as the spouts of the vessel.

The aborigines of the tribe appear to have practised this art from time immemorial: each *Gin* or wife possesses and usually fabricates her cranial calabash, with which she fetches the domestic supply of water from the pond or river, and suspends it in the hut or on the branch of an adjoining tree. They have no arts of pottery, and nature has not supplied them with vessels from the vegetable kingdom, like those which the cujete or cocoa-nut furnish to more favoured tribes.

The Scandinavian legends tell of the ancient warriors who quaffed their wine from the skulls of their enemies, but Professor Owen believed the present to be the first instance of the habitual conversion of part of the human skeleton into a drinking vessel.

On Zoological Nomenclature. By the Rev. FRANCIS ORPEN MORRIS, *B.A.*

The author, while approving of the general principles laid down in the Report of a Committee appointed by this Association to consider the above subject (1842), recommends that the Association should carry into effect its own rules, by appointing committees and subcommittees to revise the whole Animal Kingdom, and to determine the names by which each species should finally be denominated. The author further recommends that no two species (even of different genera) should have the same specific name, and that generic names should be invariably taken from the Greek, specific from the Latin languages. He also considers that the second portion of the Report, which contains recommendations for the guidance of zoologists, in future should be made retrospective as well as prospective in its operation.

On the Southern Limits of the Esquimaux Race in America.

By R. G. LATHAM, *M.D.*

It is considered that the line of demarcation drawn between the Esquimaux and Indian races of America is far too broad and trenchant. According to the evidence of language two tribes at least may be added to the former races.

1. The *Chipewyan* of Mackenzie.—This language is not to be confounded with the Chippeway (Ojibbeway), or with any of the numerous Algonkin tongues. Such affinities as it has with these are distant and indirect. Its true affinities are with the Esquimaux languages of Cadiack, Oonalashka, the bay of Kenay, and the Sitca or Norfolk Sound. It is known to us by three vocabularies, viz. the Chipewyan of Mackenzie, the Nagail of Mackenzie, and the Hudson's Bay vocabulary of Dobbs. It is spoken across the whole continent.

2. The *Ugalyachmuchtsi* of Resanoff.—The locality for this language is the neighbourhood of Mount St. Elias in Russian America. On a statement of Resanoff's it has been separated from the neighbouring Esquimaux tongues, so as to cause an appearance of discontinuity in the Esquimaux area. By dealing, however, with the Cadiack, Oonalashka, Kenay and Sitca vocabularies as the representatives of a single language, it may be shown to be Esquimaux.

Affinities of a more general kind are to be found even further southward. The vocabularies collected by Mr. Tolmie and published by Dr. Scouler in the 'Transactions of the Royal Geographical Society,' as far south as the river Columbia, are akin to each other and to the languages north of them. To these might be added two vocabularies furnished by Mackenzie, hitherto unplaced, of the *Atnah* and the *Friendly Village* languages. The first of these is closely akin to the Noosdalum, the second to the Billechoola vocabularies of Mr. Tolmie.

On the Ethnography of Africa as determined by its Languages.

By R. G. Latham, *M.D.*

In the present state of our information all classifications of the African nations are necessarily *provisional.* The classes of languages equivalent to the divisions called, in general ethnography, *Indo-European* and *Semitic,* are, for the *native* tongues of *continental* Africa, *five* in number.

I. The Coptic, containing the extinct dialects of Egypt.

II. The Berber, containing the *non*-arabic languages of Fezzan, Tripoli, Tunis, Algiers, Morocco, and the Tuarick of the Western Sahara, along with the extinct Guanche language of the Canary islands.

III. The Hottentot division.

IV. The Caffrarian division, extended as far northward as Melinda and Loango, east and west.

None of these divisions, with the probable exception of the Caffrarian, fall into any intermediate or subordinate groups.

V. The fifth and last division of the African languages falls into eleven subordinate groups, each equivalent to the divisions called Gothic, Classical, Celtic, Slavonic, &c. in general ethnography.

A. The Nubian group, containing the languages known through the following vocabularies:—

1. The Kensy of Burckhardt;
2. The Noub of Burckhardt;
3. The Dungola of the Mithridates;
4. The Barabbra of the Mithridates;
5. The Dongolawy of Caillaud;
6. The Routana of Eusebe de Salle;
7. The Noby of Eusebe de Salle;
8. The Nubian of Costaz;
9. The Koldagi of Rüppell;
10. The Jebel-Nuba of Holroyd;
11. The Shilluck of the Mithridates;
12. The Shilluck of Rüppell;
13. The Darfour of the Mithridates;
14. The Darfour of Salt;
15. The Darfour of König;
16. The Darfour of Rüppell;
17. The Darrunga of the Mithridates;
18. The Takeli of Rüppell;
19. The Denka of Rüppell;
20. The Schabun of Rüppell;
21. The Fertit of Rüppell;
22. The Darmitchegan-Shangalla of Salt;
23. The Tacazze-Shangalla of Salt;
24. The Qâmamyl of Caillaud.

B. The Galla or Danakil group, containing the Danakil, Shiho, Arkeeko, Hurrur, Adaiel and Somauli languages, as known from the vocabularies of Salt; the Danakil and Galla of Krapf and Isenberg, and the Saho of Abaddie.

C. The Borgho languages, containing the Mobba of the Mithridates and the Borgho of Burckhardt.

D. The Begharmi vocabularies of the Mithridates and of Denham.

E. The Bornou languages, containing the Affadeh of the Mithridates, the Bornou of Denham, and the Maiha numerals of Bowdich. The Affadeh of the Mithridates is probably the Bedeh of Clapperton.

F. The Mandara of Denham.

G. The Howssa group, containing, over and above the vocabularies current under the name *Howssa,* the Afnu and Kashne of the Mithridates, the Quolla-Liffa, Mallowa and Kallaghi, numerals of Bowdich; besides the Timbuctoo vocabularies of Adams, Denham, Lyon and Caillié.

H. The Mandingo group, containing the Bambarra, Jallonka, Soosoo, Sokko, Bullom, and Timmani languages; these last being related to each other and to the Soosoo. Also the Garangi, Kong, Callana, Fobee and Garman, numerals of Bowdich.

I. The Woloff languages.

J. The Foulah languages.

K. The Ibo-Ashantee group. This large and complex group falls into subdivisions: these, however, are even more provisional than the previous arrangements, since the vocabularies are in the present case pre-eminently fragmentary.

α. The Fantee languages of the kingdom of Ashantee and of Booroom. The Fetu of Muller, the Afootoo of Bowdich, the Inta, the Aowin, the Amanahea and Ahanta numerals of Bowdich are Fantee or Ashantee.

β. The Acra language of Protten and Schonning, Danish missionaries.

γ. The Dahomey or Foy languages = the Judah of Labat, and the Watje (Whidah) Atje, and Popo vocabularies of the Mithridates.

δ. The Ibo languages.

ε. The Nufee languages.

ζ. The Yorruba languages. To some parts of this group belong almost all the fragmentary vocabularies for the coast between the Sherbro and Gaboon rivers, under the various and often-confused names of

- Adampi, Tambi, Tembu,
- Akkim, Akripon,
- The Gold-coast vocabulary of Artus,
- The Asianten of the Mithridates (Ashantee),
- The Crepee of the Mithridates,
- The Adah of the Mithridates,
- The Ockwa and Wawu,
- The Kassenti,
- The Kanga, Mangree, and Gien,
- The Dagwhumba, Kumsalahoo, Mosee, Hio, Yngwa, Badagry, Kerrapay, Empoongwa (Gaboon), Oonjobai, Oongormo, Kaylee and Shekan, numerals of Bowdich,
- The few Malemba words of Bowdich,
- The Kakundy or Shabbe of Laird and Oldfield,
- The Mokko and Karabari,
- The Calbra and Camançons of the Mithridates.

The following languages, along with a few others known through fragmentary vocabularies, it is considered advisable, for different reasons, to leave at present unplaced:—

1. The Agow.
2. The Tibboo (probably Nubian).
3. The Bisharye, Adareb and Suaken.
4. The Serawoolli.
5. The Sereres.
6. The Akwambu.
7. The Croo.

On the Eastern Limits of the Australian Race and Language.

By R. G. Latham, *M.D.*

We are in possession of three vocabularies from the neighbourhood of the island of Timor, which differ materially from the Malay tongues around them: upon this account they have hitherto remained unplaced. It is believed that they are Australian, a fact which breaks down the accredited isolation of that race.

1. *Ombay.*—In Freycinet's 'Voyage' the natives of Ombay are described as having olive-black complexions, flattened noses, thick lips, and long black hair. In Arago we find about fifty words of their language; of these four are more or less Malay, whilst another group coincides with the languages of Australia and Van Diemen's Land, dealt with as ethnographically one.

2. *Tembora.*—From the Tembora district in the island Sumbawa we have a short vocabulary by Sir Stamford Raffles, together with a statement, in a subsequent letter to Marsden, that in the island in question the woolly-haired race was numerous. Without being wholly different from the Malay, it is so distinct that even its numerals are peculiar to itself. Out of thirty-four words three or four seem to be Australian.

3. *Mangarei.*—In a savage part of the island of Ende or Floris we have a short vocabulary of thirty-two words by Marsden. It is more Malay and less Australian than either of the above tongues.

On the Ethnographical Position of certain Tribes of the Garrow Hills.

By R. G. Latham, *M.D.*

In the 'Asiatic Researches' an account is given of a tribe inhabiting the Garrow hills to the north of Hindostan, whose colour and physical conformation approach the type of the negro. In the 'Asia Polyglotta' of Klaproth their language stands unplaced. The affinities of the language in question are not with the Negrito tribes of the islands, but with the continental language of Bootan, akin to the Tibetian. Hence, according to the evidence of language, the place of the Garrow tribes is with the Tibetian race.

On the Dog as the Associate of Man. By Dr. HODGKIN.

It was the object of this paper to illustrate the principle that the inferior animals, which by accident or design have accompanied man in his diffusion over the globe, may be advantageously studied with the object of obtaining some light on the obscure subject of the affinities of the several families of mankind.

The dog was naturally selected, not merely on account of his almost universal presence wherever man is to be found, but also from his tolerance of almost every climate, whilst he is susceptible of many modifications which attest the influences to which he has been exposed, and which are worthy of observation in relation to the changes which man himself may also undergo from various influences.

To avoid unnecessary complication, the author excluded from consideration the Dingo and its varieties, as found in Australia and the islands of the Pacific, and also the wild dogs of Mexico, although they appear to have furnished the Indians with some domestic animals. He likewise passed over many artificial varieties and the large group of mongrels, and proceeded to notice three principal types.

The first and most strongly marked, so extensively spread that it may be traced with such modifications of colour and size as do not conceal the family resemblance, from China to Kamtschatka, Siberia, the north of Europe, where it is familiarly known as the Spitz or Pomeranian dog, to Iceland and the regions inhabited or visited by the Esquimaux.

The second, comprising all the true hunting dogs highly endowed with the sense of smell, having the strongest marks of human cultivation, and being to a great degree dependent on man. These dogs are the blood-hound, stag, fox and hare-hounds, pointers, and perhaps some of the terriers. They seem to belong to the south-west of Asia, the south of Europe, and to ancient Egypt.

The third are the strong but active dogs, of which the earliest type is seen in the ancient sculptures of hunts, in which the game was the wild boar, the bull, the stag, &c. Of the correctness of making but one group of these dogs the author is not confident, but some animals, apparently very distinct at first sight, are found to belong to it and to be very nearly related; such are the greyhound, the bull dog, the kangaroo dog, the mastiff, Dane, Dalmatian, &c. The clashing of the family tokens of affinity and the technical characteristics of artificial classification was briefly noticed, and some generalities regarding the probable production of a few well-known and established varieties were suggested. The particular kind of Newfoundland dog, so justly admired both for its appearance and its qualities, was referred to the union of the Esquimaux dog with the *chien dogue* of the French, which, if the conjecture be true, is not without interest and plausibility with regard to the ethnology of that island. The origin of the spaniels and sky terriers was pointed out by analogous characteristics.

On the Stature of the Guanches, the extinct Inhabitants of the Canary Islands. By Dr. HODGKIN.

It is well known that prior to the discovery of the Canary Islands by the Spaniards and their subsequent occupation by the Portuguese, these islands were inhabited by a race of men of which not only many curious particulars are recorded, but individual remains of the people themselves are preserved in their mummies, which at one period were very numerous.

By many of the historians who have written of these people, either from personal observation, or so soon after the conquest that authentic information must have been readily accessible to them, the Guanches are described as remarkable for their stature, their extraordinary agility and their great strength. Dr. Prichard, in his laborious and admirable work, has, in speaking of the Guanches, adopted this description, and Sabin Berthelot, who has written an interesting article on this people, which is published in the 'Transactions of the Ethnological Society of Paris,' has mentioned authorities and quoted remarkable passages which describe the ancient inhabitants of the Canaries as possessing the qualities just mentioned.

The casual observation of Guanche mummies had previously given Dr. Hodgkin so very different an impression regarding the stature of this lost race, that his interest and surprise were excited by these relations, and he was in consequence induced to make inquiries by correspondence with his friends in the Canary Islands, and by more accurate investigation of the remains preserved in European collections.

The measurements of eight or nine individuals, males and females, of whom the skeletons are wholly or in part preserved, range from 4 feet 6½ inches to 4 feet 10¾ inches for the whole height, which exhibits a diminutive stature even for the tallest. Dr. Hodgkin does not presume to infer from the facts which he has adduced that the statements of the authors alluded to are erroneous, but he conjectures that the Canary Islands, like many other parts of the globe, may at different periods have been inhabited by people of different races, even before the arrival of the Spaniards. The people found by the first Europeans appear to have been of the same family with the Birbirs of Africa, as indicated by language, physical character, &c. They possessed however some characters which distinguished them from the Birbirs, such as the making of mummies and some other customs. The author of the paper suggested the careful investigation of all accessible relics of the ancient inhabitants, the comparison of the Guanche and Birbir languages, in order to detect in the former words distinct from the latter, and a minute reference to original writers, as affording the possible clews by which this ethnological difficulty may be overcome.

On the Stature and relative Proportions of Man at different Epochs and in different Countries. By W. B. Brent.

This paper embodied in numerous and elaborate tables the results of the measurement of some thousands of individuals, obtained from a great variety of sources, though chiefly by the personal labour and expense of the author. It is rather surprising that human anatomists should hitherto have furnished so few data or conclusions on this subject, and left a void which this paper has contributed much to fill. The author suggests that valuable statistical returns might readily be obtained in connection with the census and on other public occasions.

The author rejects the idea that tall men are deficient in mind, as hinted by Lord Bacon, and adduces historical instances of the contrary, and notices the fact that the average of stature of the inmates of hospitals, workhouses and prisons is below the ordinary average.

The average height of Englishmen is placed at 5 feet 7½ inches: the army returns, which are likely to give a good idea of the peasantry, range from 5 feet 6 inches to 5 feet 7 inches: the yeomanry, including a higher class, range from 5 feet 1 inch to 6 feet 3 inches. The French conscripts, officially stated, give an average of 5 feet 4¾ inches, but Mr. Brent, from his own observation, would place the French average considerably higher. The observations made by Prof. Forbes amongst the pupils of his own class in Edinburgh, placed the Irish as the tallest, the Scotch next, and then the English. The Belgians appear to be of still lower stature.

A fact was noticed in the paper as having been recently brought to light by the researches made by Dr. Hutchinson, in which Mr. Brent had taken a part. It was discovered that the amount of air which can be expelled from a healthy chest, after full inspiration, bore a certain ratio to the height of the individual, a certain number of cubic inches of air corresponding to every additional inch of stature. It will be obvious that the application of this principle must be of very great importance in the granting of policies of assurance on life, and in the selection of men for various kinds of public service.

A curious and interesting portion of the paper related to the relative proportions of the most remarkable antique statues; these the author has reduced to a common measure, and not content with various measurements, he has ascertained what would be their absolute weight, as men, at different statures. These results he has compared with the actual measurements and weights of a large number of the most remarkable athletæ of the present age, boxers, wrestlers, &c., as well as with those of picked men in the army and aristocracy.

On the Natives of the Hawaiian Islands. By the Rev. W. Richards.

They have no clear tradition of their origin, but they sometimes speak of their ancestors having come from Tahiti. The similarity of the Hawaiian language with that of all the islands in the Pacific east of the Friendly Islands, including New Zealand on the south and several islands on the west, proves that their inhabitants must have had a common origin. The question therefore presents itself,—In what direction did the tide of population move? If the Sandwich Islands were first settled, then they must have been settled from America on the east, or from Japan on the west. The distance from either quarter offers no insuperable objections; for several Japanese junks have drifted on the Sandwich Islands, and the same winds which bring drift wood from America might also have brought boats. But the dissimilarity between the language, habits and religion of the Hawaiians and the Japanese or Americans, amounts to almost positive evidence that the inhabitants of Hawaii could not have derived their origin from them; while, on the other hand, the author knew of no facts whatever which favour the idea of such an origin: there are however many facts which favour the idea of their having come from the south and west.

On the Sandwich Islanders. By Gen. MILLER.

On the Languages of America. By H. R. SCHOOLCRAFT.

It is admitted by philologists, that there are at least three generic languages, differing in their essential character, in that part of North America which lies between the Atlantic coast, the original seat of settlement, and the Mississippi river, extending into British America. Mr. Schoolcraft confined himself to that generic branch of its aboriginal Atlantides to whom the term Algic has been applied. This term embraces a number of languages, sub-languages and dialects, comprehending the native population of the principal part of the Atlantic coast of the United States, the Ohio and Mississippi valleys, the Valley of the St. Lawrence, the great chain of interior lakes, and extending far into the Canadas and Hudson's Bay. The Algic language is transpositive, eccretive, and highly compound, the constant tendency on the mind of the speaker being to express, along with the original idea, all its adjuncts and qualifications. Hence properties as well as things—the object acted on as well as the actor, position as well as number—are constantly associated in the sentences and words, which are uttered with a sententious formality. The tribes do not understand each other after a few removes of dialect. The Algic language is regarded as the most copious and harmonious tongue spoken by the North American tribes.

On the Natives of Guiana. By Chevalier SCHOMBURGK.

This paper was illustrated by a Macusi youth in his native dress, by several casts of natives met with on his late journey, as well as by several skulls, and by a series of drawings by Mr. Goodall. In 1840 Chevalier Schomburgk estimated the tribes who inhabit the British territory at 7000, but they have since been reduced by smallpox to 6000, but a small population for an area of 100,000 square miles. "It is scarcely necessary to observe," said Chevalier Schomburgk, "that a subject so replete with interest as the present state of the aboriginal inhabitants of Guiana deserves more attention than Great Britain has hitherto afforded it. The history of this people appears to be the end of a tragical drama, for a whole race of men is fast wasting away."

On the supposed extinct Inhabitants of Newfoundland. By Dr. KING.

Instead of being red men, as has been supposed, Dr. King produced the evidence of Thorsin, the Icelander of the tenth century, Whitbourne, who wrote in 1612, the Abbé Raynal, Lieut. Roger Curtis, and O'Reilly, in support of their being Esquimaux, and expressed his opinion that Newfoundland was never permanently occupied, but merely formed one of their fishing stations. Dr. King observed, that while we have sought for the living inhabitants we have neglected that which remains of the dead; and that future research would, in all probability, disclose that the Newfoundlanders were Esquimaux, which was the result, as far as is known, of the opening of the tumuli at the falls of Niagara.

On the Shyens and Karens of India. By Mr. KINCAID.

There are about eight millions of Shyens; they all speak the same language, and have the same written character. It is monosyllabic, and partakes largely of nasal sounds. Their alphabet is an improvement on the Burman, as it adopts only the useful consonants. They have twelve vowels which are rarely used; certain points or marks are attached to the consonants to make the vowel sounds. Their alphabet, in form, hardly varies from the Burman. The Kakhyens, Thing-bau Kakhyens, Karens and Karen-nees, are only so many different names. They are scattered over a vast extent of country and number about five millions. The account given by Marco Polo agrees with that furnished to Mr. Kincaid by the Shyens.

On Ethno-epo-graphy. By the Rev. T. MYERS.

The author's object was to furnish travellers among hitherto unknown tribes with a correct method of expressing the sounds which they hear, and forming vocabularies on the intelligible principle of using a distinct character for every sound. He used a modification of the common Roman characters, and showed how his system applied to the Arabic and Hindoo families of languages. He referred to the schemes of other orthoëpists.

On the Mode of Constructing Ethnographical Maps. By Dr. KOMBST.

MEDICAL SCIENCE.

On a Disease of the Tongue. By Dr. HEMING.

THE author described the disease, the appearances of which, although varied in degree, were uniform in character. In the early symptoms the tongue is œdematous, sulcated, and prone to become ulcerated on the borders of the sulci, or in parts which may be irritated by the contact of a decayed or ragged tooth; the surface then becomes morbidly smooth in longitudinal streaks, the papillæ being apparently obliterated; the whole organ assumes the same character, becoming dry and hard in its texture, the ulceration becomes more marked, is sometimes superficial, and in some cases forming deep ragged ulcers; in one case the ulcers had pierced entirely through the organ. The author detailed five well-marked cases; they all occurred in females, and the general constitutional health was much impaired, the patients suffering from sick head-aches, deranged digestion, œdematous ancles, &c.; in some cases the disease was of many years' continuance. In the treatment, the author deems the restoration of the general health of primary importance: after the ordinary aperients, he gave soda and cicuta, and continued these remedies many weeks. The local application found most useful was nitrate of silver; by perseverance in the treatment every case got well.

On the Bitter Principles of some Vegetables. By Prof. PERETTI *of Rome.*

The greater part of those vegetables, he observed, which contain a bitter principle not depending on an alkaloid, owe it to an alkaline resin; they are decomposed by large quantities of water, by acids, and by earthy salts. By the processes he adopted (which he described in detail), the Professor obtained the bitter principle of wormwood, quassia, coffee, gentian, &c., and also the pure bitter of bile. The bitter principle which attracted his chief attention was that of the *Absinthium Romanum*, which he stated to have much power in allaying severe irritation of the stomach, and he had successfully used it as a remedy in sea-sickness, half an ounce of the solution being enough to prevent it, or stop it if it had commenced. The Professor detailed several of the chemical properties of these resinates. The so-called resins he stated to be bi-resinated alkalies; such are the resins of jalap, guaiacum, &c. The gum-resins he stated to be combinations of resinate and bi-resinate of potash with resinates of lime and magnesia. The paper concluded by observations on some other points of vegetable chemistry, and the announcement of the discovery of a new alkaloid derived from a new species of Pereira, the *Cryptocaria pretiosa*, different from the bark of the true Pereira, examined by M. Pelletier.

On the Comparative Frequency of Uterine Conception.

By Dr. S. W. J. MERRIMAN.

On the Tape-Worm as prevalent in Abyssinia. *By* Dr. HODGKIN.

In addition to observations on this subject, he also gave some particulars of the plant called Kosso in Abyssinia, but known by different names in other regions of Africa, the flowers of which are powerfully purgative, and are used as a specific remedy for the endemic prevalence of worms.

Dr. Williams presented two specimens of Tænia, one of which had been removed by the use of spirit of turpentine, after the male fern root (*Aspidium filix mas*) had failed, and the other by the latter remedy, after the turpentine had failed.

On the Reflex Function of the Brain. *By* Dr. LAYCOCK.

The object was to show that the reflex function, as possessed by the spinal nerves and ganglia, is also manifested by the cerebral ganglia, and the cerebral nerves of sensation, the optic, acoustic, olfactory, &c.; that, in fact, as the cerebral masses and the cerebral nerves are properly to be considered as a continuation of the spinal, they are furnished with the same endowments and subject to the same laws. He reviewed the doctrine of the reflex function, and the facts on which it was founded, as taught by Dr. Marshall Hall. The excito-motory irritation may be applied either to the periphery or to the central axis in the spinal system, and may produce its effect independently of sensation or perception or volition. Yet consciousness and perception may, in some cases, be superadded to the organic effects of the irritation; examples of both those peculiarities of nervous action were alluded to; and Dr. Laycock contended, that if similar phænomena arose from mere cerebral excitement, they must be considered as reflex excited acts, accompanied by sensation and consciousness, these central cerebral irritations producing a series of changes, commencing in the posterior gray matter, and exciting what Dr. Laycock terms *ideagenous* changes; from thence the series of changes extends to the anterior gray matter, and kinetic changes (*κινέω, moveo*) result, whence the harmonious muscular movements are produced. The points insisted on by the author were, that the cerebral nerves are *incident excitor*, and the brain an excitor of movements in all respects analogous to the reflex; the proof of this he thinks must be sought in pathological observations, as those nerves are not irritable by the ordinary stimuli of heat, mechanical violence, &c., as are the nerves of the spinal axis. The phænomena of hydrophobia and chorea, he contended, furnished those proofs: in the former, the *sound*, or *sight*, or mere *idea* of water excited the convulsive paroxysm, and certain *odours* are known to excite convulsions. To show that the brain is the excitor of reflex acts, he referred to the case of chorea in the Medico-Chirurgical Transactions, and analysed its phænomena, which were complicated with spasmodic muscular movements of the face, trunk and extremities, and neuralgia of the fifth pair of nerves. Cases of lingual chorea, and partial loss of memory from disease of the brain, confirmed this view of central excito-motory power; examples were adduced. The reason why mechanical violence to the central ganglia did not exhibit these phænomena (as in the experiments of Flourens) was, because such an irritation was foreign from the true exciting influence of this part of the nervous system. The phænomena of hemiplegia were adduced as proofs of the author's position; and the instinctive actions of animals were represented as true reflex acts, induced by irritable stimuli received through the cerebral nerves.

Dr. Bacchetti communicated the particulars of a case of extra-uterine pregnancy.

Dr. Fowler communicated some additional facts relative to the case of the blind and deaf mute, which he detailed at former meetings of the Association. She had been visited by Dr. Home of Boston, the instructor of Laura Bridgeman, who found in her intellectual and moral manifestations a strong confirmation of the susceptibility of education possessed by those cases, which some doubted even after the instance of Laura Bridgeman.

Several particulars relative to the instruction of the blind were given by the Rev. W. Taylor, and some details of the instruction of a blind and deaf mute, at Bourges, by the Abbé Carton.

On the Functions of the Bile. By Dr. Kemp.

The author, after alluding to the experiments of Berzelius, by which it was proved that the bile was only in a slight degree excrementitious, concluded that it was not absorbed with the chyle *without undergoing change* from the nature of the fluid found in the thoracic duct; the object of the paper was to suggest a theoretical solution of the question of the action of the bile (chemically) on the chyme, in order to produce the chyle suitable for absorption.

On the Scientific Cranioscopy of Prof. Carus. *By* Dr. Thurnam.

On the Influence of the Endermic Application of the Salts of Morphia in painful permanent Swelling of the Joints, causing contractions. *By* A. T. Thomson, *M.D., F.L.S., F.R.C.Phys.*

STATISTICS.

On the Mining Industry of France. By G. R. Porter, *F.R.S.*

He observed that at the present time, when the most strenuous exertions were being made for the advancement of the material interests of this country in all their leading branches, and while those exertions were attended by the measure of success which usually accompanies industry directed by intelligence, it must be interesting to know whether other nations are engaged in the same pursuits, and in what degree success may have crowned their efforts. Our mining industry, if not the greatest, was undoubtedly one of the greatest sources of our wealth. Other countries had attempted to rival us so far as the means of such rivalry had been within their reach, and their governments have shown a disposition to foster and encourage pursuits from which they have expected to draw results commensurate with those which have thus excited their emulation. In no country had greater efforts to this end been made than in France. Whether the means by which success had been sought had been the most judicious on the part of the legislature of that country was, however, questionable. The latest returns having reference to mining operations in France relate to the year 1841, being five years in advance of the returns brought forward at the meeting of this Section of the British Association in Newcastle. The system of government inspection of mines was begun in 1832, during which year, as well as in 1836 and 1841, the value of the principal mineral productions were ascertained to be as follows:—In 1832, the value in sterling money was £4,230,040; in 1836, it was £6,169,138; and in 1841 it reached £7,134,243. The per-centage increase in 1836 over 1832 was 45·84, or 11·46 per annum; in 1841 over 1836, 15·64, or 3·12 per annum; and for the whole nine years, 1841 over 1832, was 68·65, or 7·63 per annum. The number of coal fields which were open in 1836 was 46; in 1841 they were increased to 62. These coal fields are situated in 41 of the French departments; two departments, which produced a small quantity of coal in 1836, have ceased to do so; but, on the other hand, thirteen departments which did not produce coal in 1836 yielded that mineral in 1841 to the amount of 160,769 tons. The total quantity of coal raised in 1841 in France was 3,410,200 tons; in 1814 the produce of all the coal mines in France was only 665,610 tons. This quantity was about double in 1826, the produce of that year having been 1,301,045 tons. In the following ten years this increased quantity was nearly doubled, the quantity raised in 1836 having been 2,544,835 tons. The increase during the last five years, to which the statements reach, has, therefore, been 34 per cent.; but, if computed upon the produce of 1814, the difference between 1836 and 1841 amounts to 130 per cent. The increase during the whole period of twenty-seven years has been 412 per cent. The number of coal mines in work during 1841 was 256, showing an average production of 13,321 tons per mine. The average production in 1836 was only 9863 tons. The number of workmen employed in raising various kinds of coal in France in 1841 was 29,320, of whom 22,595 worked in the mines. The average quantity raised to each person employed was 116 tons, being the same quantity as in 1836, when the number of persons employed was 21,913. The value assigned to the produce makes the cost of each ton in 1836 to be 11*s*. 3½*d*. per ton, and in 1841 to only 7*s*. 9¼*d*. The average value raised by each workman, which in 1836 amounted to 65*l*. 9*s*. 10*d*., had therefore fallen in 1841 to 45*l*. 1*s*. 5*d*., or nearly one-third. Whether this reduction arose from œconomy in the working, or from diminished wages or profits, did not appear. It is, however, singular that a reduction of 30 per cent. should take place in five years without preventing the continued extension of this branch of employment. The quantity of coal raised in this country is believed to be ten times the amount raised in France. The quantity shipped coastwise in Great Britain and Ireland in 1841 was 7,649,899 tons; and the quantity exported to the British colonies and coastwise was 1,848,294 tons. The quantity used in our iron works, potteries, glass works, factories, &c., is not included in the above numbers, being produced on the spot. The quantity of coal sent by canals and other modes of inland communication from the coal-fields of Yorkshire, Durham, Notts, Leicestershire, Warwickshire, and Staffordshire, amounted in 1816 to 10,808,046 tons. These quantities amount to more than thirty-four millions of tons, and as the number of persons employed in coal mines in Great Britain in 1841 was 118,233, it follows that the average quantity raised by each person is 253 tons, or about 120 per cent. more than the average quantity raised by the miners of France. After some further comments on the subject of coal, Mr. Porter proceeded to detail the statistical facts relative to iron. The increase which had taken place in this branch of mining since 1836 was not nearly so great as the increase that had attended the production of mineral fuel, for which result he accounted by the fact that the iron trade in France had not been subjected to any diminution of fiscal protection, but continues hedged round by high prohibitory duties. In 1836 there were 894 distinct establishments engaged in the manufacture of iron; in 1841 the number of distinct establishments was increased to 1023. The value of the iron and steel made in France amounted in 1836 to £4,975,424, and in 1841 to £5,671,582, showing an increase in 5 years of barely 14 per cent. The number of workmen employed in 1836 was 43,775, and in 1841 there were 47,830. The prices of iron in France are exorbitantly high—arising partly from the less efficient application of labour, and partly from the high price of fuel. Great Britain makes 4 tons of pig iron to 1 ton made in France, whilst the number of persons employed for the purpose is less in England than in France. Each person employed produces in France 8 tons, in this country more than 35 tons. The cost of fuel is very great in France, being 41 per cent. on the value of the metal made in 1836, and 38½ per cent. in 1841. Charcoal, which is very extensively used, costs 57*s*. 5*d*. per ton. The expense of conveying coals from the pits to the smelting-houses is also very great, amounting on the average to about 7*s*. per ton. The quantity of pig iron made in 1836 was 331,679 tons, and in 1841 it was 377,142 tons. Of malleable iron in 1830 the quantity was 224,613 tons, and in 1841 it was 263,747 tons. The native production was consequently greatly inadequate to supply the wants of that country; yet every obstacle was thrown in the way of importation from other countries, by the imposition of high duties. The production of metals other than iron is inconsiderable, and of no national importance, and does not at all interest us except as it points out that country as qualified to be a good customer for a portion of our superabundance. Of lead, the quantity produced in 1841 was 638 tons; silver, 73,680 oz.; antimony, 112 tons; copper, 100 tons; manganese, 1978 tons. France imports these articles to supply her wants, her lead being principally drawn from Spain, and her copper from England. The declared value of British metals exported to France in 1842 was £1,048,950, and of coals £173,278.

On Agricultural Schools near East Bourne.

Self-supporting reading, writing, and agricultural schools succeed beyond the most sanguine expectations, and afford a ready plan for teaching the poor the use of spade husbandry and engrafting in them a knowledge of the best mode of employing their hands as well as their minds. The principle adopted in these schools is to unite the present national education with agricultural instruction, by making the labours of the little scholars, while under tuition in the art of husbandry in the afternoon, to compensate the master, in the way of salary, for the instruction they receive from him in the usual course of our national education in the morning. As established at East Dean and at Pevensey, they are attended by the happiest results. The usual quantity of land required for the purpose does not exceed five acres, and for this the master pays a rent. The scholars pay each one penny per week, which, with their services, are found to be adequate remuneration to the master. He has used liquid manure, from which the best results were derived. The produce of his land in one year realised £40 after everything was paid. Some of his pupils had been eagerly engaged by the farmers in his district, and there were many other pleasing results from this new system of education. Captain Kennedy had established industrial schools in the north of Ireland; at Hardwick, near Gloucester, a similar school was established, the Willingdon school being the model which they followed. Several other instances were mentioned of the success of such schools. At one place the master maintained himself and a family of six persons on three acres of land; in another place nine persons were maintained on five acres, both of which families were previously burthens on the poor rates. Instead of being burthens on their neighbours, they are now helping to support the owner of the land by their rent, the church by their tithes, the state by their taxes, and teaching all the boys who go to them at only one penny a week to earn their livings in that state of life unto which it has pleased God to call them; they feed their native land with the surplus they raise from it, and with nerves braced by healthy toil are ready to defend it should it be attacked, and are interested in so doing, having hearths of their own to defend. Wherever fairly tried Mrs. Gilbert was of opinion that the occupation of small portions of land for manual labour has been found to improve the moral character of the occupiers. No fears of over-population ought to exist when land can be shown thus to be able to support such a number of persons. The paper gave instances of the beneficial results of the allotment system.

A specimen of wheat, bearing above 100 full ears from a single grain, was sent for the inspection of the meeting by Mrs. Gilbert.

On the Mortality of Calcutta. By Lieut.-Col. SYKES, *F.R.S.*

The paper afforded some interesting facts, showing the rate of mortality of the different classes in that place. It appeared that the rate of mortality was much greater among the Hindoos than the Mahomedans, and that the Roman Catholics in Calcutta were particularly subject to disease and death. In one return for a specified period, the number of deaths among the Roman Catholics was 12·44 per cent., of the Hindoos 5·71 per cent., and of the Mahomedans 3·47 per cent. The average of all classes was 3·98 per cent. For a period of twenty years the average deaths were $3\frac{1}{2}$ per cent. on the population generally. One table read exhibited the proportionate difference, which the deaths in the several classes bear to each other. Thus 1 Mahomedan dies to $2\frac{3}{8}$ Hindoos; 1 Protestant to $1\frac{6}{9}$ Hindoo; $1\frac{5}{6}$ Catholic to 1 Hindoo; and 1 Armenian to $1\frac{1}{3}$ Hindoo. In the military ranks it appeared that the deaths among the single officers were 3·77 per cent., and among married officers only 2·74 per cent. The paper also included tables with regard to the operation of disease upon different classes of the community.

On the Statistics of Frankfort on the Maine. By Lieut.-Col. SYKES, *F.R.S.*

The principal object of this elaborate document was to develope the vital statistics of that city; presenting copious details of the situation, origin and history of Frankfort; the plagues, fires and other disasters to which it had been subject; the persecution of the Jews resident within its walls; the nature and extent of its buildings; its defective paving, lighting and sewerage; its ramparts, which have been pulled down and the sites converted into promenades planted with trees; the constitution and government of the city, political and municipal; the administration of justice; its various public offices, its police regulations, its revenue; population, which is about 66,000; its houses, about 4000 in number; education, &c. The inhabitants and sojourners of this "free city" appear to be subject to harsh restrictions. A butcher is not allowed to sell above a certain quantity of meat; persons in service have to register themselves as such to the police, and give notice on leaving their employ; a stranger seeking work must quit the city in three days if unsuccessful; no person can marry until he satisfies the authorities that he possesses sufficient capital. The consequence of this impolitic restriction is that one in every six children born is illegitimate. State lotteries prevail, some of them displaying more ingenuity than honesty; but this does not apply to Frankfort. The indigent poor are looked after in their own dwellings, but poor-houses are provided for the houseless operative citizen or the sojourner.

On the Statistics of Hospitals for the Insane in Bengal.

By Lieut.-Col. SYKES, *F.R.S.*

It appeared from the report that there are four asylums in Bengal which are under the charge of the government authority; the rate of mortality in them is lower than that of the lunatics in the English asylums, and they appeared to be managed in a very œconomical manner. The cures and discharges in all the hospitals in 1839 was 31·7 per cent. and the deaths 16·2 per cent. In 1840 the cures and discharges were 31·1 per cent. and the deaths 12·2 per cent. Little restraint is imposed upon the patients, who for the most part are engaged in horticultural and agricultural pursuits.

On the Statistics of Old and New Malton.

By WILLIAM CHARLES COPPERTHWAITE, *F.S.S.*, the Borough Bailiff of Malton.

The paper commences with a history of the parish, and then directly proceeds to the local and geographical situation of Malton, its extent, boundary, river, &c., the statistics of its streets, number of houses in each, the number of gas-lights, the value of its houses, &c. The second section, division and tenure of property. The third section describes the population and vital statistics, with its increase and decrease at relative periods. The population in 1831 was 5377, whilst in 1841 it had declined to 5317. The registers of births, marriages, and burials were referred to, and a number of tables were produced to show the progress of mortality. It appeared that in 1810 the illegitimate children averaged 5·3 per cent.; in 1820 they were 6·7 per cent.; in 1830 they were 8·7 per cent.; and in 1840 they reached 9·4 per cent. The paper proceeded to give details of the occupations of the inhabitants in 1831 and 1841; the rate of wages paid to those employed in agriculture and handicraft; a full description of the agriculture in the parishes of Old and New Malton; the quantity of acres under the several descriptions of culture; produce of the farms; the rents paid, which were stated to average 1*l.* 15*s.* an acre including tithe, and, including taxes, &c., 2*l.* 0*s.* 6*d.*; the rotation of crops; the produce per acre; the working power; live stock; produce of butter, wool, &c.; drainage; description of soil, &c. It was stated that the tenants under Earl Fitzwilliam, the principal landowner, hold at will, but that some farms have been in the occupation of the same family for above a century. The average of the holdings is 70 acres. Mr. Copperthwaite's paper stated that the allotment system had been amply tried in Malton. There were 41 who occupied each a quarter of an acre; 54 who rented half an acre, and 26 who held an acre. There are 23 public-houses in New Malton and 1 in Old Malton, also a Temperance Hotel and some beer-shops. The paper then noticed the Temperance Society, which was stated to have had a beneficial effect; the several benefit societies, the secret orders, the savings' bank, the charitable institutions of the town, the extent of pauperism, the cost of relief under the old and new systems, the income and expenditure of the working classes, entering minutely into their domestic œconomy, the extent of markets, and the state of education. It appeared that there were 1407 children between the ages of 3 and 15 years resident in Malton; of this number 1096 were in course of education. The paper next noticed the Mechanics' Institute, the public libraries, news-room, the religious persuasions of the inhabitants, and their places of worship.

Hints on the Improvement of Agricultural Labourers.
By the Rev. THEODORE DRURY, *M.A.*

He lamented that in too many parts the agricultural labourer was depressed by poverty and degraded by ignorance; his wages were kept down by rivalry and his education was neglected. This led to despondency, wretchedness, pilfering, and daring robbery. Religion was the most energetic of all influences, and he thought it highly important that an increased attention to it should be promoted by every practicable means. The plans which he suggested for ameliorating the condition of the agricultural poor were, that a clothing club should be established in connexion with each village school; there should be a weekly sale of coals in the winter months from a store provided by the more wealthy inhabitants; small allotments, not exceeding a rood, should be let to each family; village and farm libraries and savings' banks should be promoted; and farm labourers should have their personal comforts attended to.

On the Sanatory Condition of York during the years 1839—1843.
By Dr. LAYCOCK.

The author observed that he had instituted an inquiry into the sanatory condition of York in connexion with the commissioners for examining the state of large towns. His inquiries at that time were not brought beyond 1841, but he had since prosecuted his labours, and rendered the investigation more complete, by taking in the years 1842—1843. He showed from the tables adduced that York was not comparatively an unhealthy town; but that its drains were made on a bad principle, and that the state of health had a marked relation to the altitude of the several parishes within the walls. The parishes above the mean altitude were far more healthy than those below it. The writer illustrated his statements by reference to an excellent map of the city which had been prepared by the Ordnance Office.

On the Addition to Vital Statistics contained in the First Report of the Commissioners of Inquiry into the Circumstances affecting the Health of Towns.
By Dr. LAYCOCK.

The first topic to which he would allude related to the influence of employments upon healths. Dr. Guy, of King's College, found that the proportion of consumptive cases in the several classes was as follows:—gentry and professional men 16, tradesmen 28, and artisans and labouring men 30 per cent. This great mortality from consumption among tradesmen and working men in London, he attributed mainly to their long confinement in ill-ventilated shops. Dr. Southwood Smith, of the London Fever Hospital, gave some valuable evidence with reference to the mortality occasioned by fever, showing that the comparative risk from that disease was greatest to adults, and that therefore heads of families are most liable to be cut off by it.

Dr. Laycock, in his further comments on the report, showed that investigations at Preston, Chorlton-on-Medlock, Sheffield, York and Nottingham, all led to the same result, viz. that the health of the inhabitants of various streets varied with the condition of those streets, and that children are particularly subject to the influence of noxious physical agencies.

Dr. Laycock next proceeded to notice the important evidence of Mr. Hawksley, C.E., on the supply of water to the town of Nottingham. In that town every house is supplied day and night with a constant supply of water. This advantage dispenses with the necessity of tanks and other expenses. The water-works' company supply houses at an annual average charge of about 7*s*. 6*d*. at any level required, even in the attics of four or five story houses. For a two or three story house of three rooms the charge is one penny per week, and for this sum the tenants take any quantity of water they choose; there are 5000 houses supplied at that rate. The effect produced on the habits of the people by the introduction of water into the houses of the labouring classes has been very marked. There has been a great increase of personal cleanliness and much less disease. The public drains have become cleaner, and there is less noisome stench, the refuse being washed down them by the flow of water. Nottingham is still an unhealthy town, the mean duration of life throughout England being 41 years, and in Nottingham only 30 years. This arises almost entirely from deficient public and private ventilation, from the ill-construction of the houses of the poor, many of which have privies under them and warehouses above them, in which a heat of 85 degrees is kept up.

Statistical Notices of the State of Education in York.

By JOSEPH FLETCHER, Sec. Stat. Soc. of London.

On the Statistics of the Machine-wrought Hosiery Trade.

By WILLIAM FELKIN, *F.L.S.*

He observed that the stocking trade had from a series of circumstances become almost exclusively located in the three Midland Counties of this kingdom—Leicestershire, Nottinghamshire and Derbyshire. Before the reign of Elizabeth stockings were made of coarse woollen thread, or if they were desired to be cool and elegant, they were cut out of cloth or silk tissue. The stocking-frame was invented by a clergyman, the Rev. William Lee. Finding the lady to whom he was attached pay more attention to her knitting than to his addresses, he determined to supersede her avocation by the invention of a machine for weaving stockings. He was long baffled and almost in despair, but at length succeeded in constructing the stocking-frame. Queen Elizabeth accepted a pair of stockings manufactured in his frame, and declared them most agreeable in consequence of their elasticity, and it is said she never afterwards wore any other description. After Her Majesty's death the court of James neglected the invention, and Lee retired from this country, taking with him his invention, and located himself in France, where he established a manufactory. He was flattered by the patronage of the French king, who being however subsequently murdered, Lee's prospects were blighted, and he died twenty-two years after an alien and almost broken-hearted. Lee's brother returned to England and brought his frames to London, where he carried on business for many years. For the protection of the hosiers' trade a hosiers' company was subsequently formed in London,—the arms being a frame supported by a clergyman, and a female presenting her useless knitting-skewer. The trade soon extended itself beyond the control of the company. Mr. Felkin traced the progress of the trade in the Midland Counties. In 1641 there were only two frames in Nottingham and not 100 in the whole country. In 1753, whilst the number of frames in London had decreased, those in Nottinghamshire had increased to 1500, and there were 1000 in Leicestershire. He noticed various improvements, especially one in 1759 by Mr. Strutt of Derby, who obtained a patent for his invention, and was the founder of the wealth which that family now possessed. In 1782 there were about 20,000 frames in the whole kingdom, of which 13,000 were in the Midland Counties. The trade had undergone great reverses, and at the present time the frame-work knitters were earning a lower rate of wages than nearly any other department of skilled or unskilled labourers. When they considered that the interests of 42,650 of these people were at stake, besides a like number of persons employed in winding the woollen yarn, seaming the stockings, &c., also the members of families who were dependent upon those individuals for maintenance, the statistics of this trade must be considered of grave importance. He described the labour of the frame-work knitters as very severe—requiring vigorous exertion of the hands and feet, and at the same time the greatest vigilance in watching the progress of the work. At the present time in Nottinghamshire there are 14,879 frames in employ, and 1503 which are out of employ or under repair; total, 16,382. In Leicestershire there are 18,558 at work and 2303 unemployed; total, 20,861. In Derbyshire there are 6005 at work and 792 unemployed; total, 6797. The gross number of frames in the three Midland Counties is 44,040, elsewhere in England 1572; in Ireland 275, and in Scotland 2595, making a total of 48,482. About 10 per cent. only of this number is now unemployed, being the smallest proportion ever known. Notwithstanding this apparent prosperity the wages of the operatives are miserably low, and they appear to be charged a most exorbitant rent for their frames, a rent which in some instances which were cited, pay for the frame in 46 weeks, although they are capable of being worked for a number of years. In many instances the wages of these men for a full week's work are as low as 4*s.* 6*d.* or 5*s.*, and the average appeared to be from 5*s.* to 6*s.* per week for ordinary hands. The consequence is that after they have paid their rent and other necessary outgoings, they have little left for the purchase of victuals: one family was mentioned, consisting of a man, his wife and seven children, who had to subsist for three days on a half-quartern loaf. They are in great want of clothing, and are rarely able to buy new apparel.

On the relative Liability of the two Sexes to Insanity.
By JOHN THURNAM, *M.D.*

The author thought that the opinion which appears to have recently been formed, that insanity is more prevalent amongst women than amongst men, had originated in an erroneous method of statistical analysis. Dr. Esquirol, who was inclined to this view, was at great pains in collecting information as to the proportion of *existing* cases of insanity in the two sexes, and it was found that taking the average of different countries the proportion was 37 males to 38 females. It should however be borne in mind, that in all European countries the proportion of adult females in the general population exceeds that of males. According to the census of 1841, in England and Wales there was an excess at all ages of 4 per cent., and at all ages above 15 or 20 years the excess was about 8 per cent. From 20 to 30 years of age the excess is as much as 12 per cent. Assuming only a like liability of the two sexes to insanity, it would be expected that there was a much greater number of cases of insanity among women than men. With some exceptions, however, which were accounted for by local circumstances, the author did not find that to be the case. He pointed out another fallacy in the method of investigating this subject, in consequence of the existing cases being made the basis of the calculation instead of the occurring cases. He showed that the mortality amongst insane males in public asylums exceeded that amongst insane females. At the York Asylum the mortality of the males was nearly double that of the females. The consequence is, that out of equal numbers attacked the *existing* cases of insanity in women accumulate much faster than those in men, and that they necessarily are much more numerous as compared with the *occurring* cases. In order that the comparison of the occurring cases should be a strictly accurate one, the proportions of the two sexes attacked with insanity for the first time at the several ages should be compared with the proportions in which the two sexes at the same ages exist in the community in which those cases occur. On this principle the writer had prepared a table, showing the numbers and proportion of each sex out of 71,800 cases. It appeared that out of 48,143 cases admitted into thirty-one various asylums, there were 25,601 males and 22,502 females, consequently there was an excess on the part of the males of 13·5 per cent. In nine of the English county asylums the numbers admitted were 7641 males and 6803 females, there being consequently an excess of males of 12 per cent.

The proportion of men admitted into asylums being thus shown to be higher than that of females, whilst the proportion of men in the general population, particularly at those ages when insanity most usually occurs, is decidedly less than that of women, Dr. Thurnam inferred that men are actually more liable to disorders of the mind than women. From a just consideration of the differences in the physical and moral constitution, as well as in the general prevailing external circumstances of the two sexes in civilized communities at the present day, it was, he thought, *à priori*, highly probable that men should possess a somewhat greater liability to mental disorders than women. He observed that not only are women less liable to these disorders than men, but when afflicted with them the probability of their recovery is greater, and that of their death very considerably less. After recovery, however, the probability of a relapse or of a second attack is perhaps somewhat greater in women than in men. The writer introduced a number of statistical facts with reference to the patients in the York Retreat, in illustration of his subject.

On the Financial Œconomy of Savings' Banks. By J. W. WOOLLGAR, *F.R.A.S.*

The author observed that this subject had acquired a sudden interest by reason of the scope which the new act gives to the directors of these establishments, to œconomise the management for the benefit of depositors. The question now for managers to decide was, what rate of interest is in future to be allowed to depositors? which in another form is this: by how small a proportion of the interest to be received from government can the expenses of management be defrayed? As it is desirable that the rate should be permanent, the question must be answered, not merely with reference to the present moment, but prospectively. The author pointed out the data necessary to be used in determining this question, and then put the solution in an algebraical form*, for the purpose of exhibiting the influence which the data severally have upon the result. He concluded by urging upon all managers who desired to give steadiness to the financial condition of their respective banks, two main points of regulation:—1st, that the expenses of management be limited to an amount compounded of a fixed sum, and a per-centage upon the invested capital; and as a necessary consequence of such a rule, that the actuary's salary be regulated by the same principle; 2nd, that no sum be allowed to remain in the treasurer's hands beyond the management fund, together with a very small per-centage on the invested capital. These two rules, he considered, would accommodate themselves to any variation in the amount of business, and would enable the managers to fix a rate of interest satisfactory to themselves, with justice both to the officers and depositors.

On Rural Statistics, illustrated by those of the Atherstone Union.

By C. H. Bracebridge.

The author commented upon the absence of statistical facts referring to the agricultural districts, and the anti-statistical feeling which existed therein. He thought that the modern establishment of poor-law unions might be rendered highly serviceable in the collection of statistical facts of a certain description. The points on which information might be obtained were,—1, local taxation; 2, highway rates and distances; 3, enumeration of public-houses and beer-houses; 4, population, acreage and value of land; 5, wages and cultivation; 6, sanatory, from an estimate of deaths; 7, cottages, their average rent and size of gardens; 8, education and schools; 9, notices of the geology, historical remains and families of the district. On all these points he had collected information in the Atherstone union, of which he had been for many years chairman. He had also formed a tabulated statement of the earnings and weekly expenditure of fifty families at Hinckley.

On the Statistics of the Criminal Population of Norfolk Island.

By Capt. M'Conochie.

Alluding to the nature and produce of the island, the author states that its cultivation is very laborious and its returns from crops uncertain. Nothing can exceed the vigour of vegetation on it, but the returns from its sown crops are uncertain. The average produce per acre in 1842 was, of maize, 12¾ bushels; wheat, 8 bushels; rye, 26¾ bushels; barley, 10¼ bushels; oats, 40 bushels. The surface soil is described to be very rich, but not sufficiently heavy to carry the vegetation it produces to maturity. Stock of all kinds thrive well on the island. Nothing can surpass the mutton, pork and poultry reared on it. The island is periodically visited with long droughts, when some difficulty is experienced in providing for the sustenance of the stock. No private person is allowed to keep cows or sheep, and only two persons have horses—one each. The following was the quantity of stock belonging to the government at the end of the year 1843:—22 horses, 677 horned cattle, 5352 sheep, and 405 swine. The shores of Norfolk Island abound with fish, many of considerable size and good quality. One of the greatest defects of Norfolk Island is the want of a harbour, and the consequent delay and difficulty in maintaining its sea communications. The winds are always high, and there is a remarkable equality of temperature and atmospheric pressure in all seasons of the year. The prevailing winds are from the S.E. and S.W. Norfolk Island was first occupied as a dependency on New South Wales in 1787, and was not then meant as a station for the doubly convicted, or in any way as a place of increased punishment, but merely as affording the means of distributing the prisoners. Free settlers were allowed to go with them, and gradually the population amounted

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* This formula, which in fact contains the *Theory of Savings' Banks*, is printed in Mechanics' Magazine, xli. p. 213.

to about 120 souls, besides about 250 convicts. In 1810 it was deemed inexpedient to retain the settlement on these terms; the returns from it were few and uncertain; it did not feed even its own population; the communication was uncertain and expensive; its morals became depraved; and Van Diemen's Land just then began to be settled, and not labouring under the same defects, the free settlers were offered land there, which they were compelled to accept. The convicts were removed, and the island was for fifteen years abandoned. It was re-occupied in 1825 as a penal settlement, without free settlers, and with increased severity of discipline and other management. The establishment was at first small, but rapidly increased. The convict population in 1825 was 84, in 1838 it had increased to 1447: but a large number was in the subsequent years sent to Sydney on indulgence, which reduced them to 1220: in 1840 they were augmented by fresh arrivals to 1872, but a diminution again took place, and on the 31st of December last the numbers were 1295. Tables had been carefully provided showing the country, religion and original sentences of all the prisoners who had arrived at Norfolk Island from 1825 to 1843 inclusive. The number of English were 2142; Irish, 1287; Scotch, 147; foreign, 10: total, 3592. Of those transported for life 815 were Protestants, 276 Roman Catholics, and 7 Jews. Yorkshire appears to have contributed to this penal settlement 124 convicts. An act of the New South Wales Council in 1839 facilitated the removal of nearly all the well-conducted, who had served over the periods required by it, to Sydney. That act fixed certain periods, (one, three and five years, for men under sentence for seven years, fourteen years and life respectively,) when application might be made to obtain for them the commutations prescribed by it. It in fact altogether changed the prospects of the whole body and greatly improved their condition. The real horrors of Norfolk Island terminated with the passing of this act. Before it men sent there had little or no prospect before them, except what was contingent on a capricious recommendation, which they too frequently sought to obtain by treachery, hypocrisy or other unworthy service, or despairing of attaining it they became reckless, violent, mutinous and insubordinate. This has been much changed. With good conduct on the island every one has been certain of recommendation at the allotted period of his service. Up to September 1843 there had been 1200 men thus forwarded to Sydney from the beginning of 1839. Of this number 530 have become free by the expiration of their sentence or by pardons; 670 are prisoners in New South Wales; and 36 have been reconvicted of crime. The number of reconvictions appears remarkably small, considering the description of the men, their going penniless from this island, the suspicion with which they are regarded in Sydney, and the associates to whom they return. The author then proceeded to show that in the years in which he had charge of this convict station, having introduced a more lenient system of treatment to the convicts, the number of reconvictions was far below the average, being only 1½ per cent. in four years, or ⅓ per cent. per annum. Previously, in 1839, the convicts underwent the greatest severity; the number of lashes inflicted, by sentence, for offences was 11,420. If the example of severity could deter from crime at all, these men had themselves both witnessed and experienced it in this extreme. Yet in this instance, as in so many others, it signally failed. His (Capt. M'Conochie's) object was to effect the reformation of the men under his charge. This idea had scarcely ever before been suggested to them, but they all sympathized with it, and carried it as a rule of conduct with them.

The paper next treated of those prisoners who had been sent from Norfolk Island to Sydney for trial, charged with serious offences: the next section treated of men who had absconded, with interesting details regarding each of these successful enterprises, which were attended with great daring, hazard, recklessness, suffering and peril. The author then gave statistical notices of men who have died on the island from natural causes. Those prisoners who had been sent from Sydney, where they had become seasoned to the climate, and had enjoyed full rations of food, appeared to have been less subject to disease than those who were sent to Norfolk Island direct from England. Of the former, in a population of 8059, there had been 2429 cases of sickness since 1837, or 1 in 3⅓, with 109 deaths, or 1 in 74; of the latter there were 1622 cases among 2417 arrivals, or 1 in 1½, with 80 deaths, or 1 in 30½. The author attributes this excess of sickness and death among those sent direct from England, to their rations of salt meat and maize not being adequate to support the constitution under the change of climate, with labour, after a long sea-voyage. The diseases with which they are most affected are fevers, inflammation of the bowels, dysentery and consumption. In general the men die very quietly and composedly, resigning themselves with little apparent reluctance to their fate, and receiving and applying, even the worst of them, to their own case the consolations of religion with little apparent doubt or hesitation. Thirty men have been killed on the island accidentally; seven have been murdered; nineteen have been executed, of whom thirteen were in the mutiny in 1834; seventeen were killed in resisting lawful authority; and two committed suicide. On the 1st of September 1843 there were 796 prisoners on the island, of which 447 were Protestants, 344 Roman Catholics, and 5 were Jews: almost two-thirds of these prisoners had been above ten years on the island. The proportion of married men, and consequently of suffering families, was above a fifth. The number who could read was 546; could not read, 250; could write, 403; could not write, 393. Capt. M'Conochie observed that prisoners are not generally ignorant of the first elements of education, but the degree in which they possess them is low. Among the men who could read and write not above a dozen were competent to act as clerks. He remarks, that the young English prisoners who are distinguished on the island for any degree of superior education to their fellows, are not less remarkable for their indifference to their religious duties and careless reception of religious instruction.

Notes on the Reports of the Poor Law Commissioners on the State of the Poor in Scotland. By W. P. ALISON, *M.D.*

He had at a previous meeting of the Association laid before the Section a variety of facts relative to the state of the poor in Scotland, and he proposed now to show that the evidence taken before the Poor Law Commissioners fully supported his former statements. In one point he differed from the commissioners. He asserted that one of the results of the present system was that large towns were burthened beyond their fair share with the indigent poor; in general only one-third of those on the poor-roll are natives of the towns in which they are relieved, and two-thirds are immigrants. The commissioners in their report stated that this evil had been exaggerated. He differed from the commissioners in that opinion, and asserted that the number of able-bodied persons who flock into the towns in search of work, and other classes, which he enumerated, of destitute poor not admitted as paupers, do produce an excessive burden, which under a better system of poor-law management would not prevail. He then proceeded to cite extracts from the evidence taken before the commissioners, which exhibited the great extent of misery consequent on the difficulty of obtaining parish aid in Scotland. Those for whom legal relief is extended are only the aged and the infirm; to them the amount of relief is inadequate to maintain life, and they have to resort in part, as a means of subsistence, to begging, which leads to lying and stealing. An aged disabled person is allowed only from 9*d.* to 1*s.* a week; widows left with families are allowed 6*d.* each child, with nothing for herself,—in one parish in Edinburgh which was mentioned, the usual allowance is only 4*d.* for each child and nothing for the mother. Consequently the indigent poor are in the greatest misery, and are to a large extent dependent upon the sympathy of their poor neighbours. In some parts of Scotland the poor are probably in a worse condition than in Ireland. Mendicancy is allowed in many parts, especially on Saturdays. Many families in Edinburgh are existing in rooms without furniture, and instances were given of numbers who were kept from church on the sabbath for want of clothing in which to appear. It was also in evidence that numbers of persons who are suffering these privations are of good character. Scotland has long been afflicted by an epidemic fever, which has been spread through the country by contagion from vagrants and stranger beggars; and of late a new epidemic has appeared, distinct from any other similar malady; its peculiarities are that it reaches the crisis on the seventh day, and those who survive it are subject to a relapse on the fifteenth day; in the worst cases the complexion becomes yellow, and it was first mistaken by the medical profession for jaundice. Dr. Alison has caused inquiry to be made into 1700 cases of this fever, two-thirds of which were found to be among the destitute and unemployed poor. Fifty per cent. of the poor buried at the public expense in Glasgow in 1843 were of fever. Under the present system of poor law the orphan children are deemed capable of maintaining themselves at fourteen years, and are then thrown on the world. Previously they are boarded out, in some parishes, with individuals who sometimes send them out to beg and perhaps steal. Such is the extent of poverty, that in one year seventy-nine persons were voluntary inmates of the Glasgow prison, and after remaining there for some time they were turned out, when one half of them returned, having qualified themselves by the commission of some crime. In 1842 there were in the jail at Glasgow 134 males and 124 females, whose crimes it was well ascertained arose from their inability to find employment. Dr. Alison drew a comparison between this frightful state of the Scotch poor generally and their state in Berwickshire, where more adequate poor-assessments are regularly levied, and the poor are temperate and industrious; mendicancy does not exist among them, and the evils of which he complained were nearly unknown.

On the Statistics of Health, elucidated by the Records of the Marylebone Infirmary. By Dr. Clendinning.

This infirmary is for the relief of the sick poor of Marylebone parish. During a period of 6¾ years 220 patients had been admitted monthly, of which 140 were from the workhouse and 80 from their own homes; of this number the average was 144 cures, 26 deaths, and the remainder were incurable, discharged themselves, or were dismissed for irregularity. The females admitted were 122 to 98 males.

Lieut.-Col. Sykes, on closing the Section, remarked that he considered its labours had not been either useless or unsuccessful. They had been obliged to drop some papers in order to get through the work before them. They had now run a circle of twelve years, and this session equalled, if it had not excelled, its predecessors.

MECHANICAL SCIENCE.

On the Resistance of Railway Trains. By J. Scott Russell.

The author detailed a number of experiments on the Sheffield and Manchester Railway. For the purpose of these experiments it was necessary that the railway should present long and very steep gradients. The experiments were as follows:—1. Trains of carriages, empty, were put in motion at the summit of an inclined plane, at about 30 miles an hour, and were allowed to descend freely. 2. Trains of carriages, loaded, were tried in the same way. 3. The engine and tender were treated in the same way, being put to a velocity of between 30 and 40 miles per hour, and allowed to descend freely the whole length of the inclined plane without any train attached. 4. The engine and tender, with a train attached, were propelled to the top of the inclined plane, and then allowed to descend freely by gravity. By these means the following results were obtained:—1. The resistance to railway carriages at slow velocities does not exceed 8 lbs. per ton. 2. The resistance to a light railway train of six carriages, at 23·6 miles an hour, was 19 lbs. per ton. 3. The resistance to a loaded train of six carriages, at 30 miles an hour, was 19 lbs. per ton. 4. The resistance to a light train of six carriages, at 28 miles an hour, was 22 lbs. per ton. 5. The resistance to a loaded train of six carriages, at 36 miles an hour, was 22 lbs. per ton. 6. The resistance to a six-wheeled engine and tender, at 23·6 miles an hour, was 19 lbs. per ton. 7. The resistance to a six-wheeled engine and tender, at 28·3 miles an hour, was 22 lbs. per ton. 8. The resistance to a train composed of six light carriages, with engine and tender, at 32 miles an hour [illegible]2 lbs. per ton. 9. The resistance to a train composed of nine loaded carriag[illegible] engine and tender, at 36 miles an hour, was 22 lbs. per ton. Mr. Russell observed, that the subject was [illegible] considerable importance, inasmuch as the system adopted for laying down th[illegible]nts of new lines was of necessity regulated chiefly by the opinion of the engineer [illegible] the question of resistance. How much mechanical force is required to move a given weight of train along a given gradient, at a given speed, was a question of which the solution was essential to sound engineering, but the profession had long felt that they were not in possession of sufficient data to determine this question.

On Wooden Railways. By W. BRIDGES.

This was an account of Mr. Prosser's system, now about to be tried on a branch line from Woking to Guildford. The author explained that Mr. Prosser's railway differs from the old wooden railway, in having the wood indurated by the injection of an alkaline and metallic salt, and the employment of guide-wheels, fixed at an oblique angle before and behind each carriage.

On the Advantages to be obtained by turning Canals, in certain situations and of certain forms, into Railways, especially as applicable to the circumstances of the Royal Canal lying between the City of Dublin and the River Shannon. By T. BIRMINGHAM.

Mr. Birmingham suggested, that a cheap, expeditious, safe and easy mode of conveyance could be formed along these great lines of canals. At the present moment, subsoil draining was fortunately occupying the attention of agriculturists. He, therefore, proposed so to construct the railways as at the same time to make what was formerly a canal into a drain for the waters of the country, instead of as now, in many places, especially in the case of the canal under consideration, acting as back-water upon the land: the bottom of the canal, he said, should be levelled to a reasonable incline at the various locks; that one of the present proposed systems of railways should be adopted; and that the waters which found their way into the canal should be made use of as the power, or in aid of the power, by which it should be determined that the trains should be propelled upon the railway.

On the Causes of the great Versailles Railway Accident. By J. GRAY.

From various facts and circumstances connected with the accident of the 8th of May, 1842, on the Left Bank Paris and Versailles Railway, Mr. Gray became convinced that nothing but a failure in the front axle of the Matthew Murray engine could have been the first cause of her right-hand front wheel first slipping within the rail; and having the inquiry thus far concentrated, he proceeded with an examination of that axle, and of the facts and incidents connected with its failure; and he came to the conclusion, that with good materials and proportions, and the axles in a state of repose as received from the forge, or, in other words, perfectly free from the effects of cold swaging or hammer-hardening, an axle in such a state, and of ample dimensions for its intended work, will effectually resist fracture for any period the wear of the journals may enable it to run; but if the dimensions be deficient, the iron will be taxed beyond its permanent cohesive power and elasticity; and, however slight the excess of exertion and fatigue may be, a gradual and inevitable dissolution of particles must result; but beyond this he had not met with anything, either in print, in observation, or in the course of experience, that would at all warrant a belief in iron necessarily changing its quality, or becoming crystallized by forces within the range of its permanent cohesive force and elasticity.

On Steam Navigation in America. By the Rev. Dr. SCORESBY.

Dr. Scoresby observed, that the extent of navigable waters in North America, including the coast lines and the waters of the British possessions, might be roughly estimated at 25,000 to 30,000 miles. He then alluded to the introduction of the steamboat by Mr. Fulton, in 1807, and the rapid progress that had been made, and directed attention to the peculiarities of so[illegible] the boats, the construction of the cabins on deck, and the application of the h[illegible] vessel entirely to cargo, the working of the rudder at the fore-part of the vessel by means of communicating rods, the use of a distinct boiler and m[illegible]y to each paddle, &c. With regard to speed, he observed that it was much b[illegible]d that of our steam-boats, from the circumstance of the Americans adopting the high-pressure principle, whereby, the weight of machinery being greatly reduced, the boats could run at a very light draught of water, and because also of the great length of their fast-boats in comparison of the breadth. Whilst our boats were worked at a pressure of perhaps 5 lbs. to the square inch, they thought nothing of 100 lbs. or 150 lbs. pressure. The most extraordinary performance of American steamers was effected by the J. M. White, in the summer of this year. She made her way against an average current of from 3 to 4 miles an hour, from New Orleans to St. Louis, a distance of 1200 miles, in 3 days and 23 hours, remaining a day and a half at St. Louis, unloading and loading, and reached New Orleans again, having performed a distance of from 2300 to 2400 miles in little more than 9 days. The average speed, taking advantages and disadvantages into consideration, would be 16 miles, or perhaps near 14 knots per hour.

On the New Double Piston Steam-Engine, with a Model. *By* J. G. BODMER.

The advantages claimed are velocity, œconomy, peculiar expansion, diminution of strain upon the axle, &c.

On the Œconomy of the Expansive Action of Steam in Steam-Engines. *By* W. FAIRBAIRN.

On Propelling Boats. *By* MR. SMITH.

In this communication the jet plan was advocated.

Mr. Gray enumerated a variety of experiments on iron bars, with a view to show that the want of due proportions in the several parts is productive of more or less danger.

Mr. J. Buchanan offered some observations on a new locking apparatus for carriages, which he illustrated by models. The suggested improvement arises from the introduction of the double pivot, which requires less room to turn the front wheels, and consequently gives increased space to the body of the carriage. He also exhibited some carriage springs, the improvement in which was effected by the introduction of leather packing.

On a Plan for drawing Coals from Pits without Ropes or Chains. *By* E. BOWNESS.

The advantages claimed are œconomy, durability, expedition, and compactness. The plan has some resemblance to a method which has been adopted in Cornwall for the purpose of raising and lowering the miners. The corves, holding each 10 cwt. of coal, slide in grooved rods fixed on the sides of the shaft, and are alternately seized and released by lifters attached to a rod which moves up and down in the centre of the pit by engine power; when released from the rod on its downward motion, the corves are supported by a self-adjusting pulley.

On a New Apparatus for Starting Heavy Machinery. *By* J. G. BODMER.

Upon the driving-shaft a bevel wheel is fixed at one end, and another is put on loose opposite to it, with a pinion between. To the latter is fixed another bevel wheel, and this gears into a pinion which is connected with the shaft driving the machine to be started. By applying the break to the drum to which the centre of the intermediate pinion is fixed, the machine attached will be set in motion.

On Nasmyth's Steam Pile Driver. *By* DR. GREEN.

Mr. Whitworth exhibited a new machine for ascertaining the diameter of metallic cylinders.

On a New Furnace Grate. *By* J. G. BODMER.

The peculiarity of the fire grates is, that the fire bars are made to travel from the fireplace or hopper towards the bridge, and return again to the place whence they started in the opposite direction. The object is to admit of the supply and combustion of the fuel being perfectly regulated according to circumstances, and to prevent the emission of smoke, by causing the gas generated from the fresh coal, at the time when the heat commences to act upon it, to pass over the whole surface of the ignited fuel before reaching the chimney.

Mr. Bodmer exhibited a variety of improved Cutting Tools.

Dr. Bevan explained a new Life Boat which he has invented.

On the Scantlometer. By JAMES WYLSON.

The instrument, thus named, the invention of Mr. Wylson, determines the scantlings of joists and rafters, the former level, the latter sloped to any pitch not exceeding sixty degrees, and both to any bearing not exceeding twenty-five feet. It is calculated for joists of dwelling-house floors, and rafters carrying medium-sized slating; the material fir; the distance asunder twelve inches; the rate of weight sustained supposed to be similar in all cases, and diffused uniformly throughout. The principle is stated in the accompanying explanation to be capable of application to the other timbers occurring in buildings.

Explanation of an Apparatus, invented by Mr. Littledale *of York, by which the Blind can write and read. By the* Rev. W. TAYLOR, *F.R.S.*

The following is a description of the instrument:—"Into a case, probably a yard long, and three or four inches square, is fitted a slide, something like one section of a letter-rack used in printing-offices for depositing the type when not in use. This slide is adapted to any alphabet or to arbitrary characters. At one end of the case there is a hammer, under which the paper is placed, and as the letters are brought up successively, by the application of an ingenious contrivance at the opposite end of the case, the hammer is raised, and by its fall they are impressed or rather embossed upon the paper, so that blind persons may distinguish them by the touch. When the first letter of a word is printed the hammer is raised, and that causes the letter to move away, and at the same time a space on the paper for the next letter is produced. The blank between each letter or word may be increased by raising the hammer twice or thrice instead of once. The successive letters are brought up to the hammer, by the means before alluded to. There is also a prepared paper (black), which may be put over the white paper at discretion, the object of which is to enable persons who have their sight to read the printing better, the force of the hammer causing the black paper to 'set off.' At the hammer end of the case a piece of cloth is attached, to place between the hammer and the type, so that the letter may not be bruised. The type in the slide was made of wood, but to metallic letters the instrument would be equally applicable."

On the Improved Compasses of M. De Sire Lebrun, *and the Cold-drawn Pipes of* M. Le Dru. *By* O. BYRNE.

Explanations of the Barege Mobile, or Canalization of Rivers, and of the Grenier Mobile, or moveable Granary for preserving Corn. By O. BYRNE.

The latter machine consists of a cylinder, divided into compartments, which will hold 800 quarters of corn. It is made of zinc and galvanized iron, and turns round like a barrel, so that the grain is thus turned over by one man daily. The advantages are, that the corn gets gradually dried, may be preserved for a longer period, bad corn is improved, grain generally comes out heavier than when it went in, and is not bruised and wasted by being turned over with the shovel. With regard to the increase it was stated at 6⅔ lbs. in 110 cwt. The cost of the machine is about 1*l.* a quarter.

On the Construction of Buildings for the Accommodation of Audiences. By Sir T. DEAN.

In this communication the author gave an account of alterations, which in consequence of Mr. Scott Russell's paper on the subject, he had been enabled to make in the defective arrangement of the Court House at Cork. By adapting Mr. Russell's general principle to this particular case, he had succeeded in rendering the feeblest voice effectively heard.

On the Collection of Water for the Supply of Towns. By JOHN BATEMAN, *C.E.*

Mr. Bateman is of opinion that one-half or three-fourths of the rain is allowed to waste away, and often to do great damage, and suggests that it should be collected in large reservoirs and conveyed thence to towns in the locality*.

On the Œconomy of Artificial Light for Preserving Sight.

By I. HAWKINS, *C.E.*

Few were aware, he said, of the injury inflicted on the sight by too much or too little light, and by a sudden transition from gloom to light. He had tried several experiments with a view to procure a light of a medium description. He commenced with two common candles of eight to the pound, alternately snuffing and leaving them unsnuffed, and measuring the intensity of the light by the shadows on the walls. The result of this experiment was, that he found that the candle well-snuffed gave eight times the light of that which was unsnuffed. He then proceeded to a process of weighing, and found that one pound of the snuffed candles gave as much light as nine pounds of the unsnuffed candles. With regard to Palmer's and the common dip, he found that a pound and a quarter of the latter, costing 5½*d.*, when well-snuffed, was equal to one pound of Palmer's, costing 6½*d.*; but when the same candle was not snuffed oftener than about every ten minutes, it took four to be equal to Palmer's; and, when unsnuffed altogether, it required eleven pounds to be equal to one pound. After alluding to further experiments with candles, and also with oils, he concluded by recommending the self-snuffing candle in preference to oil-lamps.

On a new Process of Magnetic Manipulation, with its Effects on Hard Steel and Cast Iron. By W. SCORESBY, *D.D., F.R.S., Lond. & Edin., Member of the Institute of France.*

During two or three sessions I have had the honour of bringing before the Section, the progressive results obtained in the course of a long series of investigations on the magnetic phænomena exhibited by steel plates and bars of various qualities and degrees of hardness. In a work recently published, entitled 'Magnetical Investigations,' comprising a detailed account of the researches referred to, it has been shown that no *general* rule could be given for the construction of magnets, as to the best denomination of steel or degree of hardness; but that the variations in the masses and proportions, as well as in the forms in magnets, require, beyond certain extents of difference, a different rule. A similar difficulty, in practical magnetics, is found in the determination of a rule or process for the magnetising of bars or plates, under varieties of condition as to mass, proportions and hardness. Two processes, indeed, described in Part I. of the 'Magnetical Investigations,' are most *extensively* applicable (if the developing or induction magnets be sufficiently powerful) for *straight-bar* magnets of almost all varieties of mass and temper, or hardness. These processes, modified as required by the peculiarity of figure in horse-shoe magnets, are likewise very effective for this description of magnets of the qualities *ordinarily* constructed. Neither of the processes, however, nor any process that I have seen described, is found to be constantly effective in the case of *thin hard* bars of the *horses-shoe form.* Where the thinness and hardness are extreme, the effectiveness of the usual processes are most liable to fail.

The uncertainty of the result, with these most usual methods, induced me to try other processes, suggested by the principles previously investigated. But none of the known processes, as appeared from the irregular application of the magnetical forces in the course of the manipulations with a horse-shoe magnet, were satisfactory,

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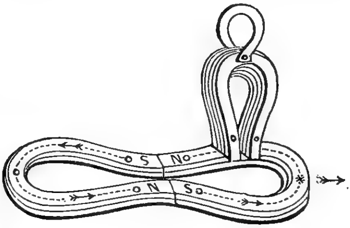
* On this subject, Mr. Bateman has undertaken to present a Report to the next Meeting.

nor, in all cases, successful. The cause of the failure of the general processes, where a horse-shoe magnet was employed, seemed to be the production of consecutive poles. The action of a powerful magnet applied to a hard thin bar seemed *too local*; so that in the passage of its two nearly contiguous poles, a kind of magnetic wave is raised, highest under the magnet, which leaves behind it, probably, like the passage of a ship or boat, a series of other waves of diminishing altitude.

To remedy this supposed defect in the ordinary processes, I placed two pairs of thin horse-shoe shaped magnets upon each other, each pair arranged in the form, nearly, of the figure of ∞, with converse poles in contact. The arrangement was such, that whilst the two bars of each series or stratum, as laid on the table, had their converse, or mutually attracting poles in contact, the two series had correspondent polarities laid on each other. The annexed figure represents the arrangement and the position of the operating magnet nearly at the commencement of the process. The compound or operating magnet is placed on the upper surface of the upper pair of bars at the curve with its N. pole towards the S. and the S. towards the N. of the bars to be magnetized. It is then slid gradually forward, S. pole in advance, towards the end designed for the N. pole of the bar beneath, and continued across the junction of the bars, in the course of the dotted line, keeping the axis of the two poles in the central line of the bar, until the magnet comes round to the point at which the process commenced; it is then slid off in the direction of the small arrow-shaped mark. The upper pair of bars is then removed and the lower pair turned over: the upper pair being also turned over is replaced on the top, and the process of manipulation, changing also the poles of the operating magnet, is repeated. Two complete circuits being thus made on the two surfaces of the upper pair of bars, developes in the highest possible degree (if the operating magnet be sufficiently energetic) the magnetic power of the lower pair of bars, whilst the upper pair is found to be comparatively weak. Before separating either pair of bars, those above must be removed; and then, if the highest capacity be wished to be determined, a separate conductor should be laid across the two poles of each magnet to sustain the power when they are separated..



The effect of this process may be advantageously illustrated by giving the powers of the bars of a small five-bar magnet, weighing altogether 2·86 lbs. as magnetized in a *single* series in the form above figured, and when magnetized (taking the powers of the lower pair) by the process now described. These bars, it should be noted, were of best shear-steel, annealed in oil (after being made quite hard) at a temperature of about 490°; so that the process in the *single* series was much more effective than in the case of harder bars of similar thickness. The powers of the bars were determined by a spring balance, and those registered are the powers *after* the removal, at least once, of the iron conductor, so that these may be considered as the *permanent* powers. In the employment of the *double series* process of magnetizing, it will be observed, that there must be two bars left, after the magnetizing of three others, whose highest magnetic energy could not be developed, if no additional or subsidiary bars were used. But in this case I employed two bars of a corresponding kind belonging to another magnet for completing the process. If no additional bars are in possession of the magnetizer, then similar bars of *iron* can be substituted, or, without a spare bar of any kind, one of the two bars employed as the upper series in the previous manipulations can be magnetized by placing the other upon it, and an iron conductor across the poles of each bar whilst the manipulations are in progress. There will then remain only a single bar to be magnetized by another process. The following comparative experiments show the advantage gained by the new *double-series* process over that of the single series, or of any other method previously in use, for all the modes heretofore described were tried.

Powers of bars by the single series process, in figure of ∞ combination	7; 7; 7·4; 7·4; 8·3. Total 37·1.
Powers obtained by the double series process	9·5; 9; 9; 10; 10·7. Total 48·2.

These powers, it will be noted, are very unusual. The last bar of the series was found to weigh 4050 grains. Its lifting power, therefore, was not less than eighteen times its own weight—a degree of energy, in a magnet of such a weight, as I had never before witnessed. The average power of the set of bars was 9·6 lbs., or nearly seventeen times the average weight. The load sustained when the five bars were put together as a compound magnet was of course much reduced proportionally. Before the removal of the conductors, indeed, the small magnet supported a weight of 44·5 lbs.; after the breaking of the contact, it sustained a load, rapidly but progressively attached, of 27 lbs., or *above* nine times the weight of the instrument.

The same process of magnetic manipulation, in which the magnetic energy is developed through the medium of an interposed bar or bars, is found to be exceedingly effective in its application to *cast iron* bars of the horse-shoe form. Through the kindness of my friend Henry W. Wickham, Esq. of the Lowmoor Iron Works at Bradford, I obtained bars of cast iron of the best quality, and made *very hard* by being cast on a cast iron plate, for a large compound magnet of the horse-shoe form of this species of iron. The bars measured twelve inches from the curved extremity to the poles, and weighed on an average about 5·8 lbs. Their capacities for magnetism, as developed by the new process, proved to be very considerable.

Magnetized in the single series form, by a very powerful horse-shoe magnet, is the best mode hitherto described; the lifting powers of four of these bars were,—

First trial, before the separation of the conductor.	*Subsequent or permanent power.*
14; 9·5; 7; 12. Mean 10·5 lbs.	12·5; 7; 7; 8. Mean 8·5 lbs.

Magnetized by the new, or double series process, the powers were,—

23·5; 17·5; 18·5; 18. Mean 19·5 lbs.	15·0; 10·5; 10·5; 11. Mean 11·8 lbs.

Straight bars of thin hard steel were next subjected to trial by the same process, and its efficiency in developing the utmost power of the bars, by the agency of a horse-shoe magnet, was again proved. In this case three hard steel plates were placed in a straight line at the end of each other (according to a well-known arrangement), these being magnetized by a single strike of a horse-shoe magnet from end to end, with a similar series of hard plates interposed. *Each* of the three plates of the *lower* series was found to be magnetized to saturation. A result, apparently similar, but not yet strictly tested, was obtained by one stroke of the horse-shoe magnet over a single hard cast steel plate, with a *plate of iron* interposed. Here the iron acted as a conductor along the whole magnet, so as to render the formation of a parallelogram of two steel bars with iron conductors across the ends unnecessary.

Thus by means of this new process, the principle of which simply consists in the developing of the magnetic energies of a magnetizable substance, not by the direct action of a magnet, but through the medium of a magnetizable substance of like dimensions interposed, the horse-shoe magnet, an instrument so compact and convenient for practice, becomes available for the magnetizing of almost all kinds of bars or plates capable of being constructed into permanent magnets.

On the Great Fountain at Chatsworth, erected by the Duke of Devonshire. *By* Mr. Paxton.

This fountain is supplied with water from a reservoir which covers eight acres. The fall is 381 feet, and the height which the water attains from the fountain, (or which it is expected to attain when brought into full operation,) is 280 feet*.

On the Filtration of Water for the Supply of Towns. *By* B. G. Sloper.

The high-pressure plan, through sand, was recommended.

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* A report on this subject has been undertaken.

On a Plan for Preventing the Stealing of Letters by Letter Carriers.
By the Rev. F. O. Morris.

Mr. Morris proposes that a stamp (similar to the one at present in use) be imprinted on a slip of paper about half an inch wide and twice the length of a folded letter; the price a penny, as at present. Let this stamped slip be put through the letter, which may be done either before or after it is folded, and then be doubled inwards, so as for the ends to meet. It will keep in by the mere doubling down, but if additional security be thought desirable, these ends may be fastened together with a wafer, &c. Let this stamped slip be directed, as well as the letter itself, by the writer, and let it be stamped at the office where it is put in, as well as where it arrives, as also the letter itself, as is done with the latter at present. When such letters arrive at their destination, let the slips be pulled out, and filed, or those of each day put by themselves, for any fixed time, for reference if necessary. Detection would thus, on inquiry, immediately follow the detention of any letter.

On the probable Mode of Constructing the Pyramids.
By Henry Perigal, *Jun.*

The author, after quoting from Herodotus the description of the building of the great Pyramid, and commenting on the magnitude of some of the stones employed in it, and of others found in the ruins at Baalbec, gives the following explanation of his views.

There appears to be no evidence to prove that the architects of the Pyramids were acquainted with any contrivances or combinations equivalent to what would be called machines or engines, according to the modern acceptation of the words; on the contrary, it seems much more probable that their gigantic undertakings were accomplished by some very simple means; which simplicity (leading to the notion that the means were self-evident) was perhaps the very reason that no record was kept, or transmitted to posterity, of their mode of operation. With this conviction, on the assumption that the statement of Herodotus might be founded on fact, I endeavoured to discover in what manner such prodigious blocks *could* have been elevated, from step to step, *merely by the aid of short pieces of wood*, when the idea occurred to me that they *might* have been so raised by some such system as the following process:—

Each block of stone, shaped and prepared for use before it left the quarry, was conveyed across the Nile (advantage being taken of the periodical inundations) on rafts, or other appropriate vessels, to the causeway described by Herodotus; along which it was dragged on rollers, or on sledges if the stone was smoothed or polished, by the labour of men (or of cattle), to a convenient locality adjoining the Pyramid, where it remained till wanted; thence it was conducted to the first step of the Pyramid on rollers. To get the rollers underneath wedges were used, if it lay on the hard rock; otherwise the earth was removed from beneath one-half of the stone, the director or superintendent having placed himself upon the further end to prevent it from tilting over too soon.

Next, the director having walked on the top to the other end, the stone (overbalanced by the leverage of his weight) tilted into the hollow in the ground, when rollers were placed under the other half of it.

The director having walked back again the stone was tilted on to the rollers, and conveyed to its destination at the foot of the Pyramid; where, perhaps, it was transferred in a similar way to larger rollers.

Then commenced the lifting process. All but one roller being removed, that one being as nearly as possible under the centre of gravity, the stone was tilted as before, while flat boards or planks were placed beneath; and upon these boards another very much narrower to act as a fulcrum: all being about the same length, proportioned to the width of the stone.

The director having walked to the other end the stone was tilted on to the boards, and similar planks were piled beneath by the side or parallel to the others, but a degree higher or more in number; and upon them also a narrow fulcrum-slip, upon which the stone was then tilted.

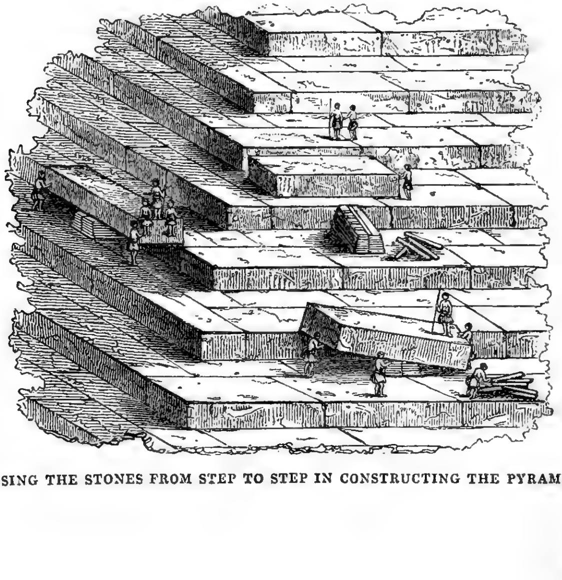
The director having repeatedly walked backwards and forwards, tilting each end of the stone alternately, and additional boards having been introduced every time, the stone gradually rose to the required height, rather exceeding that of the next step, when rollers were placed on the boards and the stone was transferred to similar planks placed in readiness on the next step of the Pyramid.

The same process was then renewed, and *continued from step to step* till the stone arrived at its destined locality.

Should any of the stones have been short, and consequently have afforded insufficient leverage for one man's weight to tilt them, he might have carried a load; or planks might have been made fast at the top so as to project beyond the ends of the stone for him to walk along; or two or more men might have been employed in traversing the stone; or various other expedients might, obviously, have been adopted to tilt the stone. The wood probably underwent some preparatory process by which it was condensed and its elasticity destroyed, perhaps by being subjected to very heavy pressure when sodden with boiling water.

Thus "the properties of the lever and of the centre of gravity were brought into co-operation, so that *the weight to be lifted was itself the principal element of the lifting power*." Figuratively speaking, THE STONE WAS MADE TO RAISE ITSELF BY MEANS OF ITS OWN WEIGHT.

In this manner, with the aid of a few dozen planks, a couple of men (one traversing the stone while the other arranged the planks) *might* have conducted to the top of the great Pyramid the largest stone used in its construction; thus corroborating the assertion of the Egyptian priests, as stated by Herodotus, that the "*stones were raised from step to step by the aid of short pieces of wood; which, being portable and easily managed, might be removed or transferred as often as they deposited a stone; or different sets might have been employed for every range of steps.*" By this simple process, also, a few men might have raised Stonehenge in a single night, if the requisite stones were provided and placed in readiness near the spot, without any previous or subsequent indication of the means by which it was effected; affording the Druids a favourable opportunity of practising upon the ignorance and credulity of the multitude by ascribing its erection to supernatural agency.



RAISING THE STONES FROM STEP TO STEP IN CONSTRUCTING THE PYRAMID.

ADDENDUM.

On Photography. By H. F. Talbot, *Esq., F.R.S.*

[*Article omitted in its proper place, p.* 37.]

Mr. Fox Talbot said that he had made many experiments on sulphate of iron as a photographic agent; attention having been called to the subject by Mr. Hunt. He could not recommend the use of succinic acid. The same iodized paper as was used in the calotype process, gave the best results. With this and sulphate of iron he had obtained portraits in one or two seconds.

This process, then, only differed from the calotype process in using sulphate of iron instead of gallic acid to bring out the picture. He therefore objected to the introduction of a new name; for since other substances (such as tea, tannin, &c.) possess this *bringing out* property, and probably many more will be discovered in future, each of these would require, upon the same principle, to have a separate name, which would be productive of inconvenience rather than advantage.

2. The spontaneous development of pictures in the dark, was a thing of constant occurrence in the calotype process (which indeed was first discovered in that manner). Moreover, when the *io-gallic* paper, formerly described by Mr. Talbot, is employed for calotyping instead of *iodized* paper, no second wash is required to *bring out* the pictures, which develope themselves spontaneously after removal from the camera; and therefore the process which Dr. Woods recommended was not new in this respect. The time necessary for the complete development of the pictures varied considerably, according to circumstances, from a few seconds to one or two hours.

3. In reference to Prof. Grove's communication, Mr. Talbot reminded the Section of the account he had formerly published of the *positive* variety of the calotype process, in which an iodized paper not *really* but *virtually darkened* by light, is again *virtually whitened* by exposure to light in the camera, the final result being *brought out* by gallic acid in the usual way. By operating with these *virtual* papers, the time required for a *positive* camera picture was greatly shortened. Still however it was ten times longer than for the negative process, and therefore there was room for improvement in this branch of photography. The *positive* camera pictures are very beautiful, having of course all the delicacy of first impression, which is lost in transferring the image to a second sheet of paper.

On Mineral Springs and other Waters of Yorkshire. By William West.

Entering the county from the south, we have at Birley Spa, Hackenthorp, four miles from Sheffield, a slightly saline spring, and a saline chalybeate; the former contains per imperial gallon—

Sulphate of soda	7·44	
Chloride of calcium	1·01	
Carbonate of lime	·55	—Total... 9 grains.

This supplies hot baths, and a remarkably commodious plunge bath. The chalybeate contains—

Sulphate of soda	40	
Sulphate of lime	22·5	
Carbonate of lime	·5	
Protoxide of iron	4·	—Total... 67 grains; including a minute trace of magnesia.

The two are within a very few yards of each other.

On the gritstone moors, to the west of Sheffield, I found springs and streams of the purest natural waters I have ever examined; the proportion of solid matter was less than two grains per gallon, and some of the substances present required for their detection that the water should be much concentrated; when this was done their nature was found to be as complicated as in ordinary waters, sulphates, muriates, and carbonates, with lime, soda, magnesia and iron, for bases.

The waters of Askern near Doncaster, have long enjoyed some celebrity, and several sets of baths exist there. I analysed several of the springs about five years since. I found in the Old Manor Baths,—

Sulphate of magnesia	153·18	
Sulphate of soda	58·06	
Chloride of calcium	82·83	
Carbonate of lime	12·05	
Carbonate of soda	30·19	Total... 236·31
With Sulphuretted Hydrogen	8	
Carbonic acid	5¼	
Nitrogen	8	Total... 21¼ cubic inches.

Three other springs, supplying the baths of various proprietors, were so nearly alike in their results that one statement may be sufficient.

Sulphate of magnesia	17·75	
Chloride of calcium	3·9	
Sulphate of lime	103·8	
Carbonate of lime	12·2	
Carbonate of soda	26·35	Total... 164.
With Sulphuretted Hydrogen	6½	
Carbonic acid	8¾	
Nitrogen	11	Total... 26¼ cubic inches.

I satisfied myself by passing the electric spark through portions of the residual nitrogen, mixed with various proportions of oxygen alone, and of oxygen and hydrogen, that no appreciable quantity of carburetted hydrogen or of oxygen was previously contained in the water.

No other Yorkshire water, except Harrowgate, contains nearly so large a quantity of magnesian salts, and there the chloride, not the sulphate, is present. The wells at Askern, however, were at that time so badly secured, and the strata in which they occur are so porous, that the water varied to an unusual degree. I found neither iodine nor bromine by careful search in these waters.

At Stanley, two miles north of Wakefield, there was, some years ago, an Artesian or overflowing well, which supplied one of the strongest solutions of carbonate of soda, almost without earthy salts, which I have met with; it contained

Carbonate of soda	40·8	
Sulphate of soda	5·8	
Chloride of sodium	8·9	
Chloride of calcium	2·1	Total... 57·6.

At Field Head, in Mirfield, is a strong run of water, powerfully chalybeate, with 4 grains of oxide of iron, 25 of sulphate of lime, and 61 of sulphate of soda. It well illustrates the observation that such a proportion of iron may accompany a large or a very small quantity of alkaline and earthy salts.

The water distributed from the present Leeds water-works is supplied by several springs and streams in the neighbourhood of Eccup. I found these to contain

from 2·35 to 3·63 Sulphate of lime.
1·33 to 4·27 Carbonate of lime.
1·38 to 5·97 Carbonate of soda.
Traces of magnesia, and in some cases of iron.
7·7 to 11·65 total solid contents.

At Leeds we have a water of considerable local repute and some scientific interest. It has long been obtained in abundance in the township of Holbeck, and hence such water, wherever met with, obtains among Leeds people the name of Holbeck Water. The best springs yield

Carbonate of soda	38·4	
Chloride of sodium	4·2	
Chloride of calcium	·6	Total... 43·2.

It might serve as a subject for chemical speculation, and as yet we have little beyond speculation in such matters, that in these waters, where the principal salt is carbonate of soda, we always find sulphuretted and often carburetted hydrogen. But carbonate of soda often forms a secondary impregnation without being accompanied by either of these gases.

It is a little singular, this variety of water being so extensively met with in this county, that it should either be rare, or have excited little attention in other parts of the country. It is scarcely mentioned in chemical treatises.

This water is deservedly in high repute for some domestic purposes; but I think sufficient attention is not paid to the medicinal effects, whether beneficial or otherwise, of a long continuance of even small doses of carbonate of soda, when these effects are increased, like those of other substances, by the state of dilution and the bulk of fluid. Lastly, such is the inaptitude of some persons for judging of the qualities of a water without analysis, that I have met with some who considered every water obtained by *boring* as "Holbeck water," and expected it to answer all the purposes of that really valuable kind. One spring of this description, passing under the name of Holbeck water, yielded

Sulphate of lime	35·27
Carbonate of lime	6·1
Carbonate of soda	18·63——Total... 60, including traces

of chloride of magnesium.

Or supposing the interchange between the carbonate of soda and its equivalent of lime, on concentration in the boiler to be complete there would remain

Sulphate of lime	3·16
Carbonate of lime	32·00
Sulphate of soda	24·84——Total... 60.

In fact, instead of the boiler remaining clean, as with carbonate of soda alone, the "fur" was taken from it, in frequent cleansings, by barrow loads.

At Calverley near Bradford, is a powerful chalybeate, in which the iron is in the state of sulphate, with much sulphate of lime, but I have no account of the exact proportions.

Among the flag-stones to the north and west of Bradford are many excellent springs, which I have had occasion to analyse; the following are among them:—

Sulphate of lime	2·35	Sulphate of lime	2·7	2·35
Sulphate of soda	1·37	Carbonate of lime	·2	1·67
Carbonate of soda	·28	Carbonate of soda	2·5	2·48
Total...	4·		5·4	6·5

Occasional traces of chlorides in some specimens.

The water at Ilkley, lately ushered into fresh notice by the establishment of baths and the other adjuncts of the cold water cure of Preissnitz, under the new appellation of Ben Rhydding, I have not had occasion to analyse. It has been stated to owe its chemical distinction to extreme purity, but the analysis does not bear out this account.

Chloride of sodium	·657
Sulphate of soda	·366
Sulphate of lime	·2
Carbonate of lime	2·353
Carbonate of magnesia	1·04
Silicate of soda	1·066
Peroxide of iron (?)	·060——Total... 5·742.

The proportion of solid matter is small, but greater than in the Sheffield or the Bradford waters.

At Skipton there are hot and cold baths, supplied by a spring, slightly saline and sulphureous.

At Crickhill, between Skipton and Gisburn, is a sulphureous spring; the saline contents are—

Chloride of calcium	25·76
Chloride of sodium	15·94
Sulphate of soda	48·4
Carbonate of soda	15·4
Oxide of iron	·5 ——Total... 106.

And the gases,—	Sulphuretted hydrogen	2⅓	
	Carbonic acid	4	
	Nitrogen	4⅔	
	Carburetted hydrogen	4	Total... 15 cubic inches.

At Bolton by Bolland, on the extreme western verge of the county, in the grounds of Mrs. Littledale, is a weak sulphureous spring: though unprovided with baths, and indeed too small at present to supply them, it has credit in the neighbourhood as a medicinal water, for both internal and external use.

The water of the Aire and the Wharfe, at their sources near Malham, is strongly petrifying; large masses of calcareous deposit abound among the cliffs of Gordale Scarr; Josh. Spence found 12½ grains of solid matter per gallon, of which 12 grains was carbonate of lime.

Huddersfield has in its neighbourhood two sets of baths; at Lockwood, one mile south, the water is sulphureous, containing

Sulphuretted hydrogen	1·836	
Carbonic acid	·756	
Carburetted hydrogen	3·78	
Nitrogen	4·428	Total... 10·8 cubic inches.

The only solid contents are carbonate of lime, 7·8; sulphate of magnesia, ·8; and a trace of chloride of calcium.

Here we have the compounds of hydrogen with carbon and sulphur, without their usual accompaniments of chlorides or carbonate of soda.

At Slaithwaite baths the characteristic ingredient is carbonate of soda; the analysis of two springs gave me—

Chloride of calcium	·75	·7
Chloride of magnesium	·4	·4
Chloride of sodium	2·65	2·5
Carbonate of soda	17·8	20·4
Total...	21·6	24·

From the construction of the pumping apparatus, large bubbles of gases continually escape and may be inflamed by a candle; these, from their burning with a blue flame and sulphureous smell, are believed in the neighbourhood to be hydrosulphuric acid, "sulphur" as they term it; they consist, however, of a small quantity of that gas, with much carburetted hydrogen and some nitrogen and carbonic acid. The waters yielded

Sulphuretted hydrogen	·75	
Carbonic acid	1·25	
Carburetted hydrogen	4·75	
Nitrogen	6·25	Total... 13 cubic inches.

The excellence of a pure sodaic water for steam-engines is well illustrated here; I was assured that the bottom of the boiler which supplies the pumping-engine and hot water for baths remains "bright like silver;" this I suppose an exaggeration, but that it never requires cleaning is a circumstance more credible and sufficiently desirable.

At this spot I found, in greater abundance than anywhere else in my experience, that remarkable substance, the organic composition and equivocal nature of which has exercised the ingenuity of chemists.

Not far from the baths is a chalybeate spring, yielding—

Sulphate of soda	1·7	
Carbonate of lime	3·	
Carbonate of magnesia	2·1	
Protoxide of iron	1·8	Total... 8·6.

I had an opportunity of examining the ordinary waters of the neighbourhood of Huddersfield on the north side, from analysing many springs about Honley; they gave from 2 to 12 grains of solid matter, generally about 8, of which about half consisted of salts of lime.

Horley Green, one mile and a quarter north-east of Halifax, is the site of a powerful chalybeate spring; I found—

Sulphate of iron	40·77	
Sulphate of lime	15·26	
Sulphate of magnesia	5·	
Chloride of calcium	·32	
Silica	·93	
Alumina	1·22	——Total... 63·5.

On the south bank of the river Wharfe, at Boston, or Thorp Arch, a strong saline spring supplies hot and cold baths; its composition I found to be—

Chloride of sodium	822·	
Chloride of calcium	59·	
Chloride of magnesium	11·5	
Silica	1·25	
Carbonate of iron	1·75	——Total... 895·5 grains.

It was natural to expect iodine and bromine in water containing so large a proportion of chlorides, but I could not in any state of concentration detect either. This water has been said to contain hydrosulphuric acid, which, as may be supposed from the composition, is a misrepresentation, arising from the wish to bring the baths into closer competition with those of Harrowgate.

The celebrated Harrowgate springs might of themselves furnish a long dissertation; I shall make it as short as their number and importance will permit, analyses by others as well as by myself having been published repeatedly within the last few years. The *Old Well*, which forms the type and standard of all the sulphureous waters of the place, yielded on the last occasion on which I analysed it,—

Chloride of sodium	872·4	Sulphuretted hydrogen	15·6
Chloride of calcium	94·1	Carbonic acid	2·72
Chloride of magnesium	45·7	Carburetted hydrogen	6·86
Carbonate of soda	34·8	Nitrogen	8·82
Total number of grains	1047·	Total number of cubic inches	34·

As on former trials, I found no sulphates in the water; when these have been met with, I have no doubt sulphuric acid has been formed in the water, from keeping, or from the action of heat during evaporation. I found iodine and bromine distinctly on evaporation, as well as a minute trace of potash.

Dr. Watson, in his well-known essay, speaks of three other springs as situated close to the Old Well; these have been long covered in, but the spot was opened in 1836; No. 2 was not, I think, found, but Nos. 3 and 4 then contained—

	No. 3.	No. 4.
Chloride of sodium	852	737
Chloride of calcium	83	69
Chloride of magnesium	43	40
Carbonate of soda	10	9
Sulphate of soda	2	16
Total number of grains	990	871

And of gases,—

	No. 3.	No. 4.
Sulphuretted hydrogen	7	3
Carbonic acid	6	6
Other gases, chiefly nitrogen	12	14
Total number of cubic inches	25	23

These springs appear, like No. 1, or the Old Wells, to have increased in strength since the time of the earlier published analysis. I found in

Dec. 1823 ...	1025 grains of salts.	May 1836 ...	1066 grains of salts.
May 1830 ...	1016.	May 1844 ...	1047. ... ...

The spring which approximates most closely in composition to the Old Well is Thackwray's, containing

Chloride of sodium	802·	Sulphuretted hydrogen	21·6
Chloride of calcium	77·5	Carbonic acid	4·32
Chloride of magnesium	38·5	Carburetted hydrogen	5·76
Carbonate of soda	32·	Nitrogen	4·32
Total number of grains	950·	Total number of cubic inches	36·

Repeated trials at intervals of several years, sometimes in the way of complete analyses, sometimes directed to those points alone, confirm the general facts of this water remaining almost uniform in composition, but with less salt and more sulphuretted hydrogen than the Old Well. Several springs in the same grounds approach to, but none reach this, the earliest of Thackwray's springs.

The wells on the Common, near the Bog, are too shallow, too unprotected, and even too shifting in their situation to preserve similar uniformity, but I think enough may be discovered from their analysis to disprove the popular opinion that "the moss is the mother of the waters;" the strongest of these springs yielded—

Chloride of sodium	329·
Sulphate of soda	6·0
Chloride of calcium	27·8
Chloride of magnesium	17·6
Carbonate of soda	3·2
Total number of grains	384·

And of gases,—

Sulphuretted hydrogen	4·5
Carbonic acid	5·4
Nitrogen	8·1
Total number of cubic inches	18·

Several of the minor sulphuretted springs are similar in composition to this, including Starbeck and Bilton Park.

Though the sulphuretted springs form the great attraction of Harrowgate, the chalybeates are numerous, and would of themselves supply a watering place; the Old Spa contains 10 grains of solid matter, of which 2·5 is oxide of iron, held in solution by carbonic acid, the remainder various earthy salts. Other springs yield 1·8, 2, 1, and ·75 oxide of iron, with similar quantities of earthy or saline matter.

Oddy's saline chalybeate, if it remains constant, may well form a distinct class; I found it in 1830 to contain—

Oxide of iron	5·3	
Chloride of sodium	577·2	
Chloride of calcium	43·5	
Chloride of magnesium	10·	——Total... 636 grains.

In the water of a celebrated spring, the Dropping Well at Knaresborough, I found—

Carbonate of lime	23	
Sulphate of lime	132	
Sulphate of magnesia	11	
Carbonate of soda	6	——Total... 172 grains.

A trace of iron.

If we suppose, contrary to Dr. Murray's hypothesis, all the lime, or a proportionate part of the magnesia, to exist as carbonate, the carbonate of soda will be replaced by sulphate, and this takes place on the deposit of the tufa or petrifactions; but it is worthy of notice, that, independent of the oxide of iron, to which these owe their colour, the concretions are not pure carbonate of lime, but contains both sulphuric acid and magnesia.

About two miles to the westward of Harrowgate we again meet with the sodiac water to which I have had so frequent occasion to refer, but less pure than in some other situations; three wells at Harlow Carr yielded—

Chloride of calcium	4·73	8·85	4·77
Sulphate of magnesia	1·15	2·91	1·56
Carbonate of magnesia	6·93	8·48	8·23
Carbonate of lime	5·88	·12	5·84
Carbonate of soda	14·11	17·64	12·9
Total...	32·8	38·	33·3

And of gases,—		
Sulphuretted hydrogen	2 to 3	cubic inches.
Carbonic acid	6	... ...
Nitrogen	8	... ...

There are also several chalybeate springs, of which the strongest contains—

Oxide of iron	2·16	
Other substances	8·24	Total... 10·4.

All the springs and streams yet mentioned are in the West Riding. In Harrowgate alone I think I have examined nearly fifty springs.

In the North and East Ridings of the county my own analyses have been less numerous, and of a considerable part I do not know the localities with sufficient exactness to give the same interest, and the waters are less marked in character; a few only need be particularized.

In the North Riding, at Hovingham, the sodaic water occurred in a strong and strikingly pure condition, yielding 38 grains of carbonate of soda and 3 grains of common salt, without a trace of sulphates or any earthy salt. It is accompanied by sulphuretted hydrogen, but I had not an opportunity of analysing the gases on the spot, the only mode in which exact results can be obtained.

The Scarborough water has I believe been found to vary by different chemists; I give Prof. Richard Phillips's analysis, 1840:—

	North Well.	(Dry salts.)	South Well.	(Dry salts.)
Chloride of sodium	26·64	26·64	29·63	29·63
Cryst. sulph. magnesia	142·68	69·6	225·33	109·91
Cryst. sulphate of lime	104·	82·2	110·78	87·6
Bicarbonate of lime	48·26	26·23	47·8	26·
Bicarbonate of protox. iron	1·84	·87	1·81	·86
Total	323·42	205·54	415·35	254·
Salts by direct evaporation		212· gr.		260· gr.
Gas,—nitrogen	6·3 cubic inches		7·5 cubic inches.	

At Filey, a few miles south of Scarborough, a spa exists, rather strongly impregnated, and with salts of considerable medicinal power, viz.—

Sulphate of magnesia	48·96	
Chloride of magnesium	36·4	
Chloride of calcium	41·2	
Chloride of sodium	210·8	
Carbonate of soda	58·08	Total... 395·44 grains.

I have notes of several analyses of waters for railway use from the East Riding; a very few shall suffice.

	Gallow Creek.	Heple.
Carbonate of lime	8	15·5
Sulphate of lime	7	3·
Sulphate of soda	47	
Chloride of sodium	17	20·5
Total	79	39·

The waters of York have received more attention in the way of analysis than almost any other; in a pamphlet published by my friend Joseph Spence, and in Dr. Laycock's Sanitary Report, ample details will be found, which I scarcely need copy; the points most remarkable in the whole of those made by Joseph Spence are a proportion, comparatively large, of nitrates and of potash, both believed, justly I think, to be derived from rubbish on the surface. W. White of York, also found nitrates in two waters, and I can confirm the fact of their occurrence from a slight examination recently made by myself.

To those who would trace a connection between the geology of a spot and the chemical character of a spring issuing from it, a matter which I have only touched incidentally, I would observe that they must descend from those comprehensive views of geological formations which embrace provinces, kingdoms and continents, to the most minute kinds of examination. We find within a few yards or a few feet of each other, springs largely impregnated with certain constituents, and springs entirely free from these, but abounding in others of a different description, and all of these springs well-marked, distinct, perennial in flow, varying within very narrow limits in composition, and within those limits remaining the same for centuries. Simply to refer the strata in the localities where these springs break forth to one or other *series* of rocks, or even to a single formation, will do very little to aid the attempt to determine where and how the water which originally descended in a pure state as rain, has received its saline or gaseous impregnations. The part which pure chemistry has commenced is to make exact analyses of many waters, and to collect accounts of such, scattered as they generally are, in scientific journals, or in the hands of the proprietors of springs.

Hereafter we may have to examine more extensively and more strictly the sources of their ingredients, but it is the first of these tasks which, so far as Yorkshire is concerned, the present report attempts in some degree, and to the extent of present existing materials, to accomplish. Much, it will be seen, remains to be done in the way of exact analyses; but there is sufficient to show that for those engaged in such investigations, this county, especially in the West Riding, offers a very copious field for research.

Omitted in the Report for 1843.

On Industrial Education. By HENRY BIGGS.

After alluding to the historical facts connected with this subject, the author argued that the alternation of physical with mental exercise is not only beneficial in respect of health to youth, but especially valuable in inducing habits of early industry and order among the children of the poor. He gave minute statistics of the following schools from personal observation:—

Upper Norwood, a contractor's establishment, 1100; Lower Norwood, a school for the pauper children of Lambeth, 300; Tooting, a contractor's establishment, 300; Limehouse, a district school for the children of the Stepney union, 400; Ealing, a school founded and endowed by Lady Noel Byron, for the sons of peasantry, 110.

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TO

REPORTS ON THE STATE OF SCIENCE.

INDEX II.

TO

MISCELLANEOUS COMMUNICATIONS TO THE SECTIONS.

THE END.

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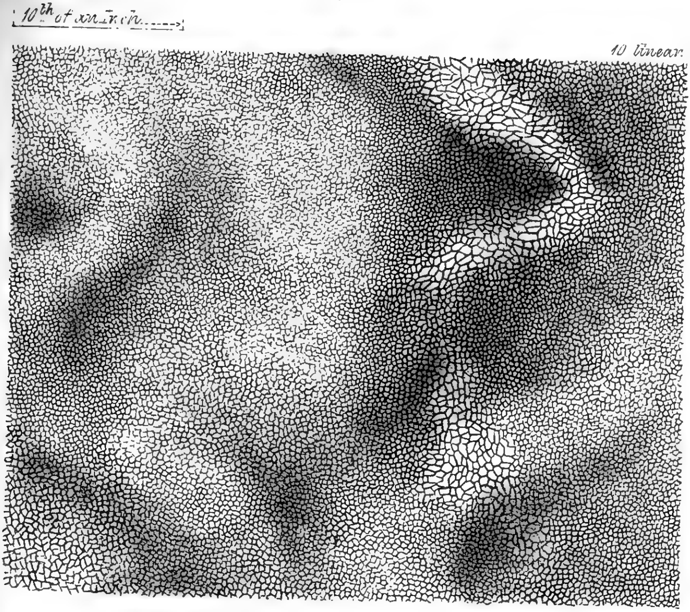
Fig. 1.



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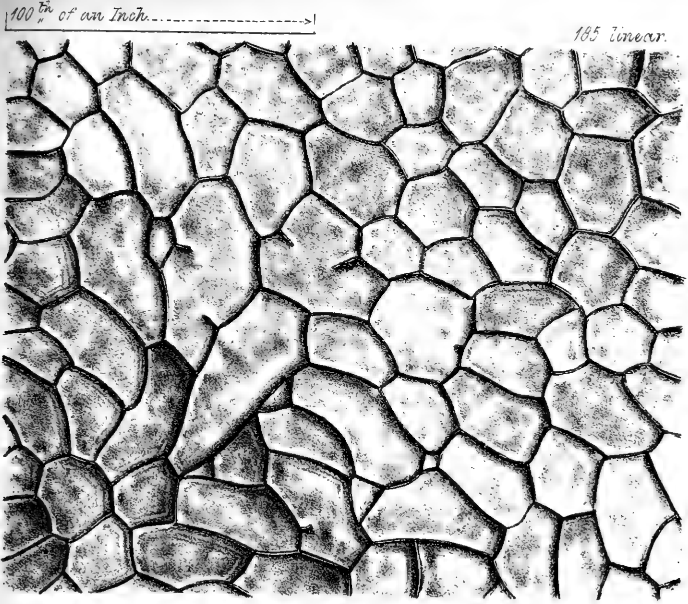

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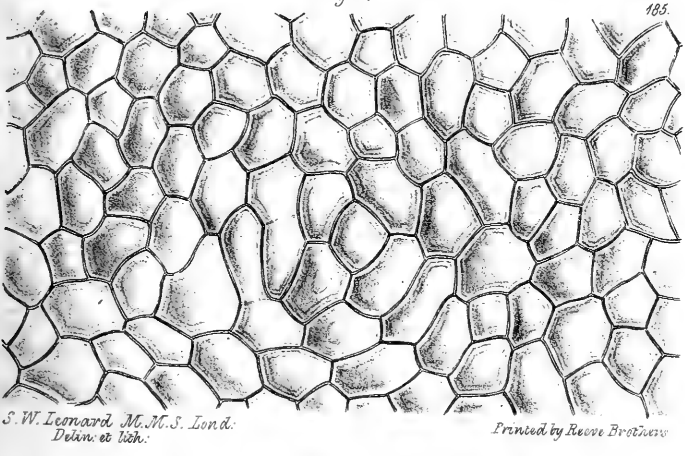

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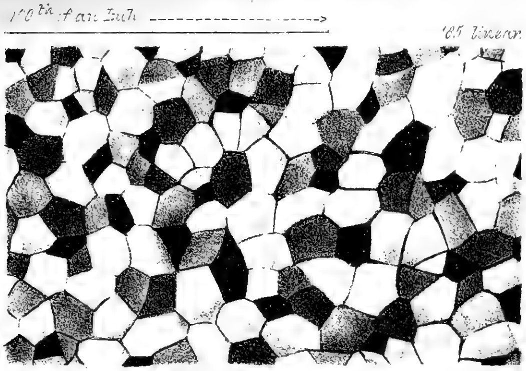

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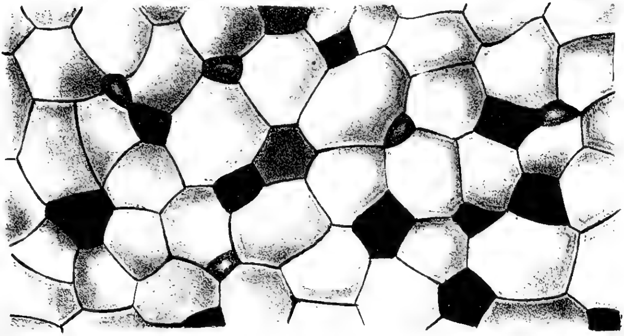

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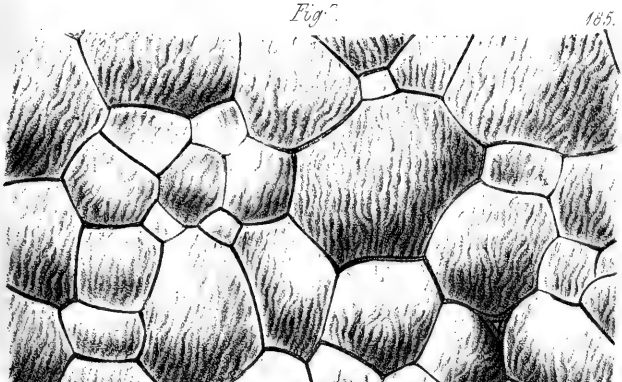

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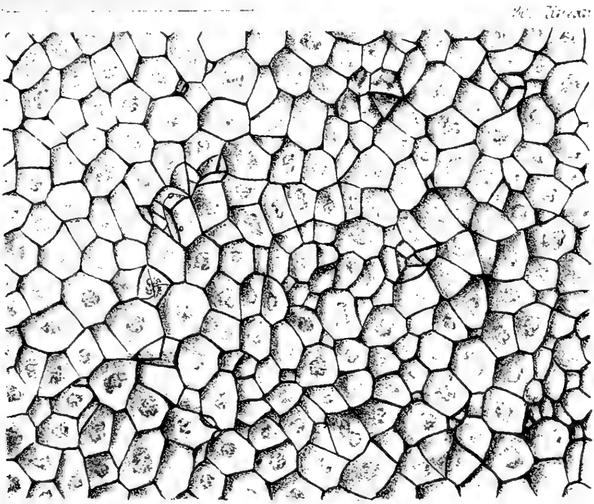

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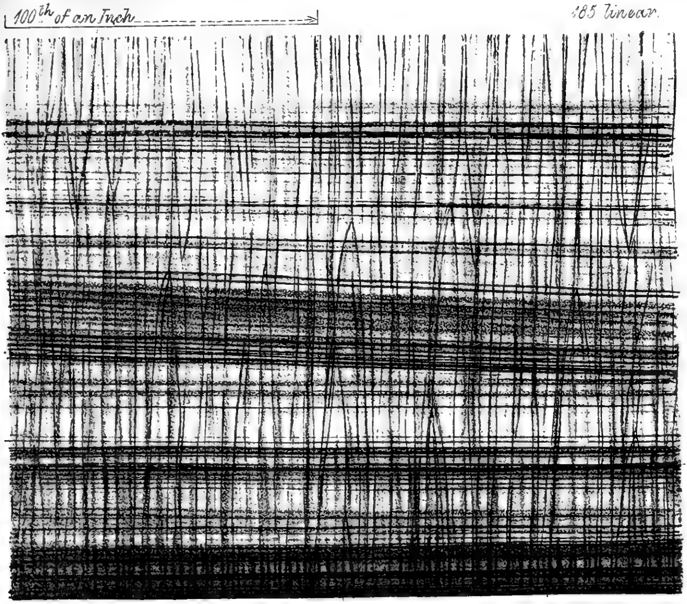

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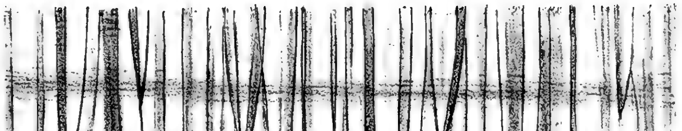

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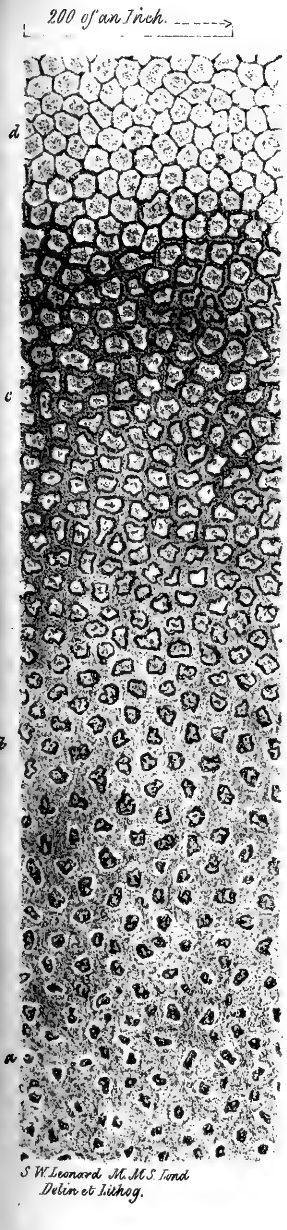

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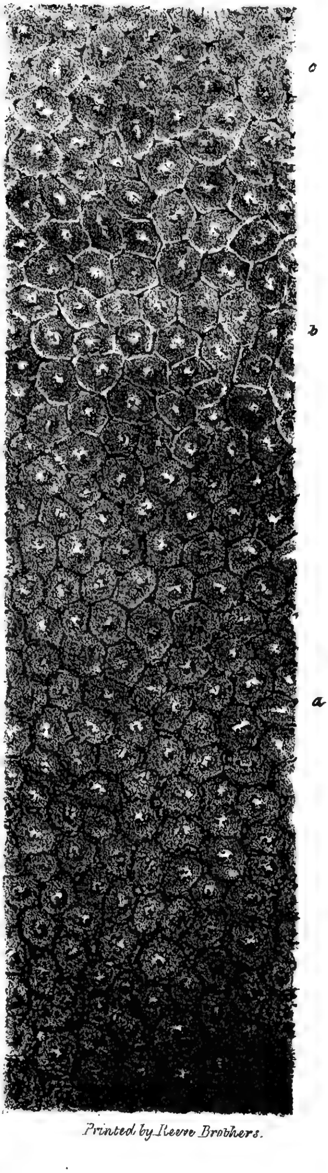

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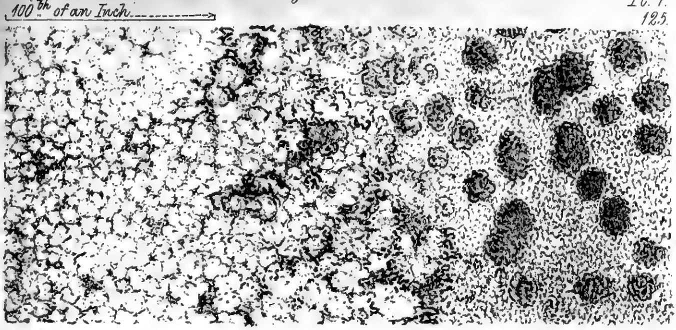

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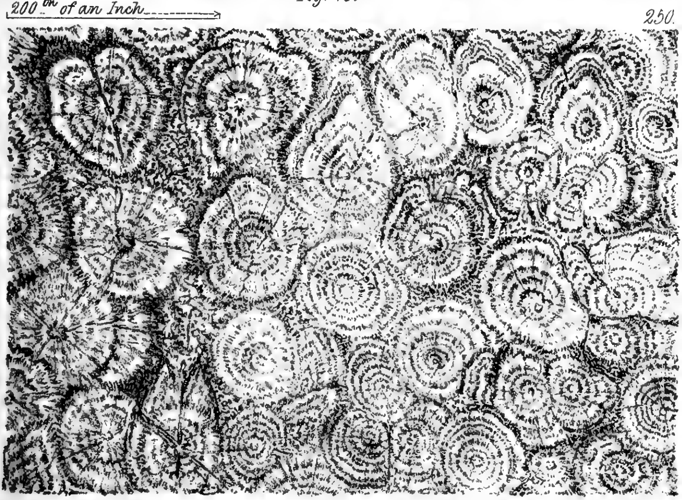

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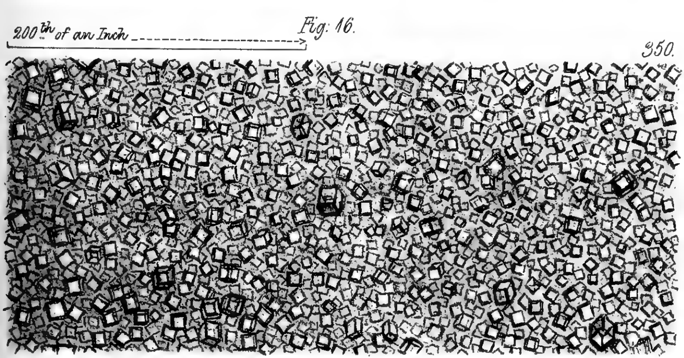

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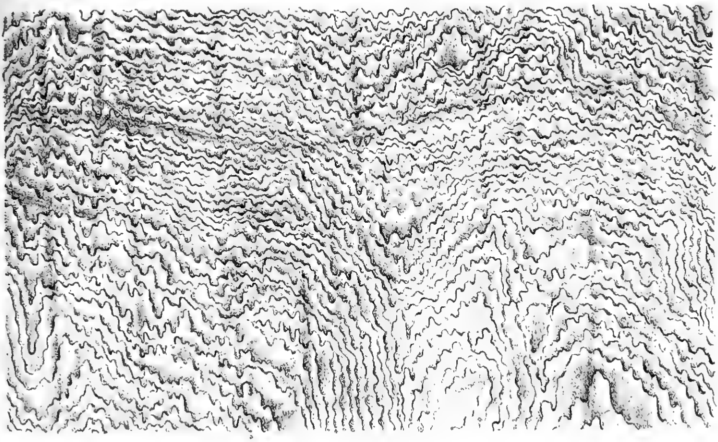

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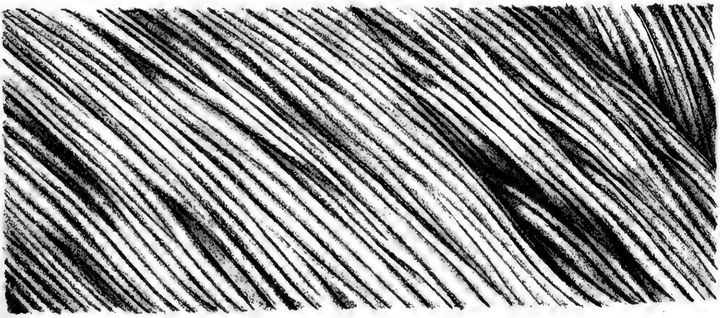

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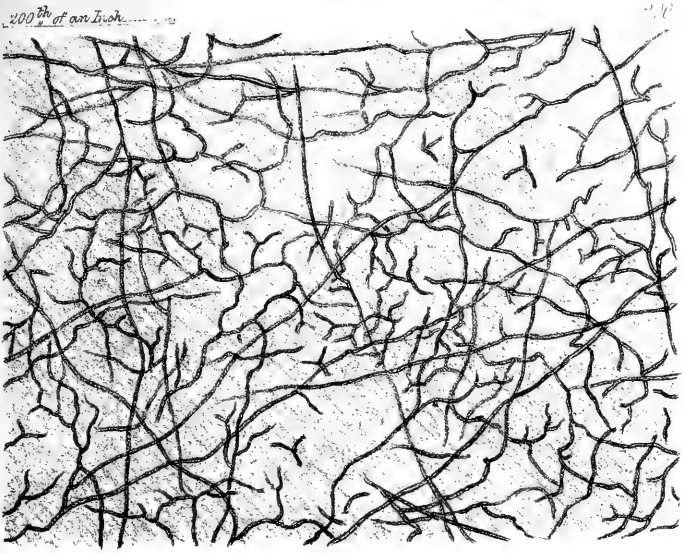

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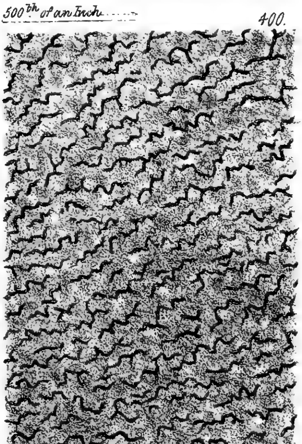

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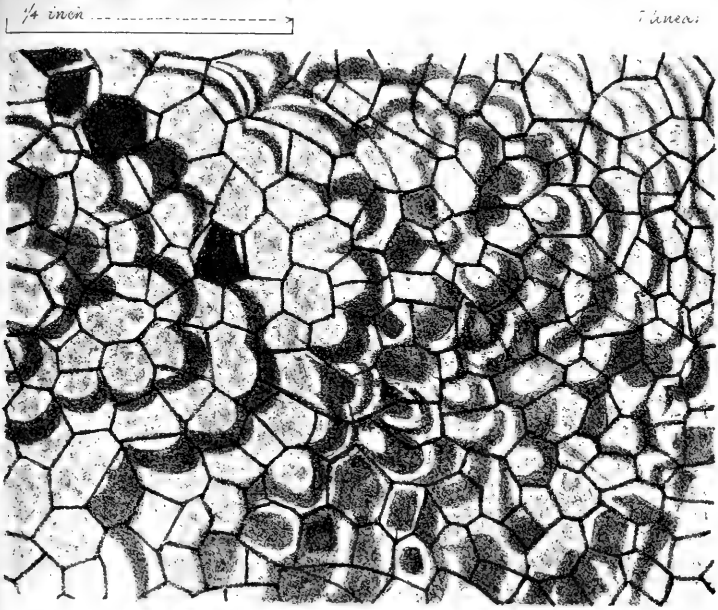
Fig. 23



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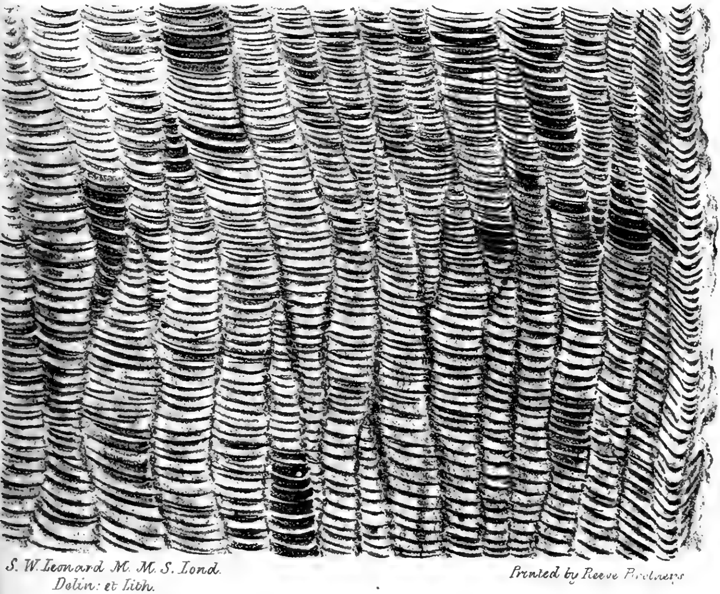

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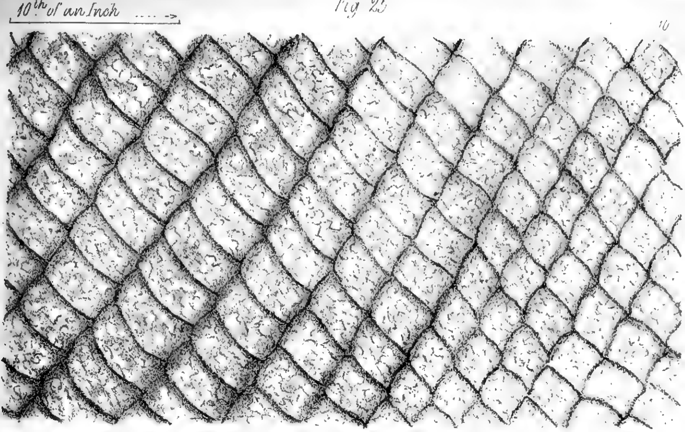

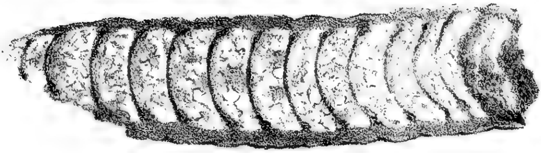

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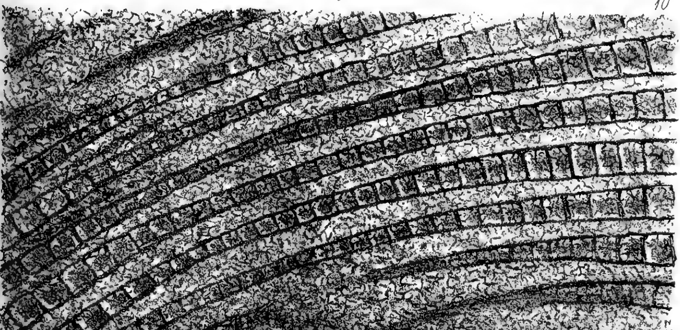

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Fig. 27.

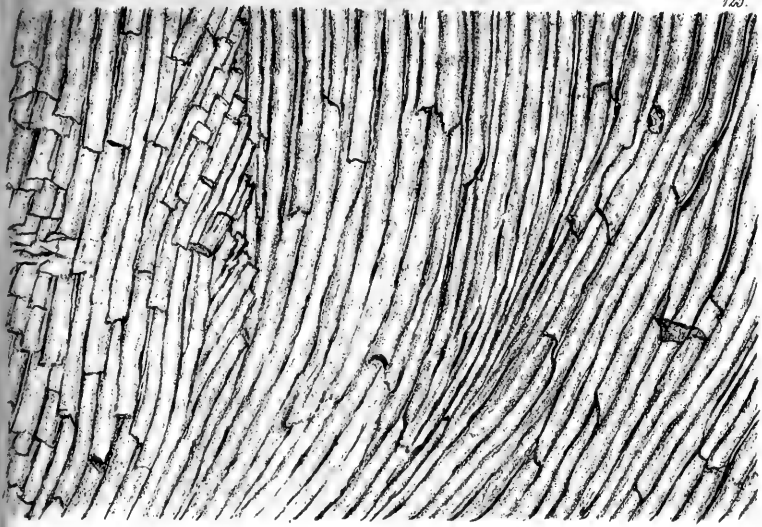
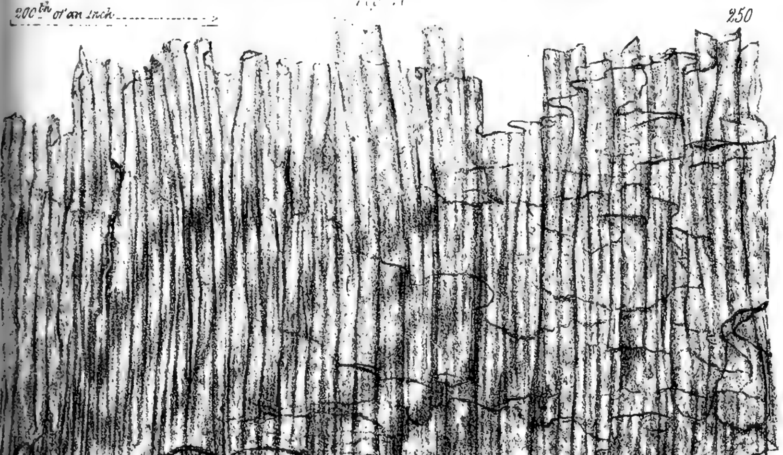


Fig. 28



S. W. Leonard M.M.S. Lond
Delin et Lith.

Printed by Reeve Brothers.

Fig. 29

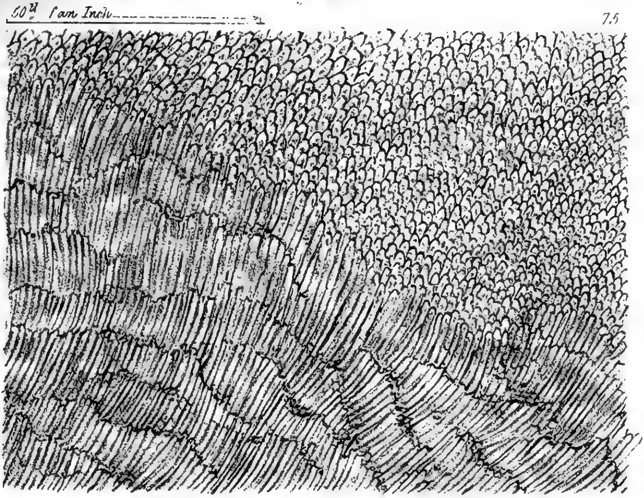
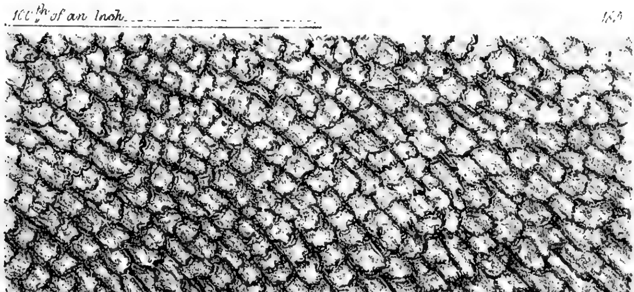


Fig. 30



S. W. Leonard. M.M.S. Lond
Delin et Lith.

Printed by Reeve Brothers.

Fig: 31.

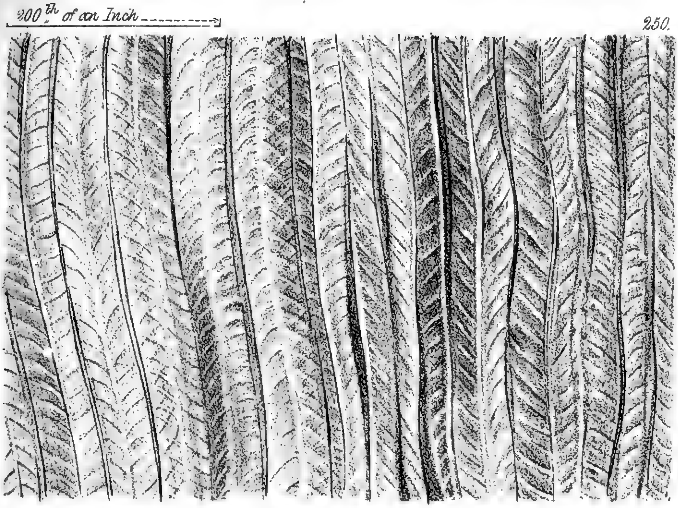
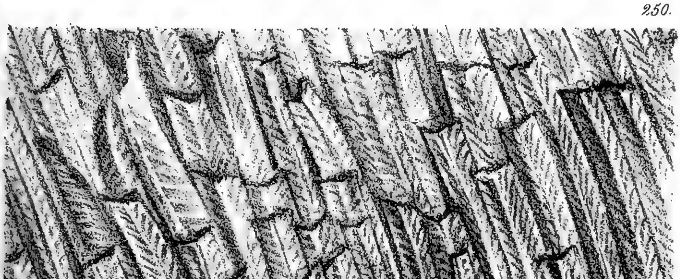


Fig. 32.



S. W. Leonard M.M.S. Lond:
Delin et Lith.

Printed by Reeve Brothers.

Fig: 33

50th of an Inch

15

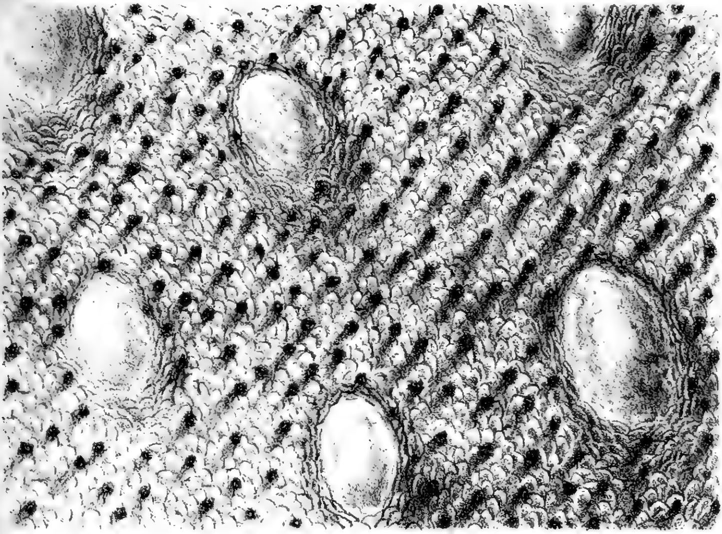
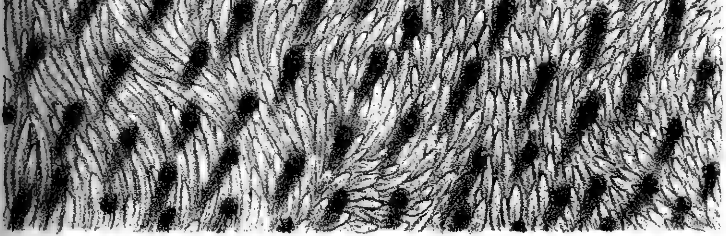


Fig 34

100th of an Inch

125.



S. W. Leonard M. M. S. Lond.
Delin et Lith

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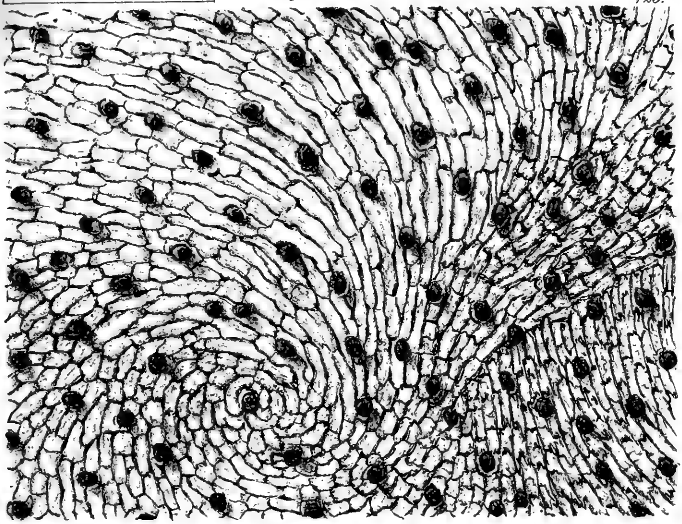
Fig. 35.



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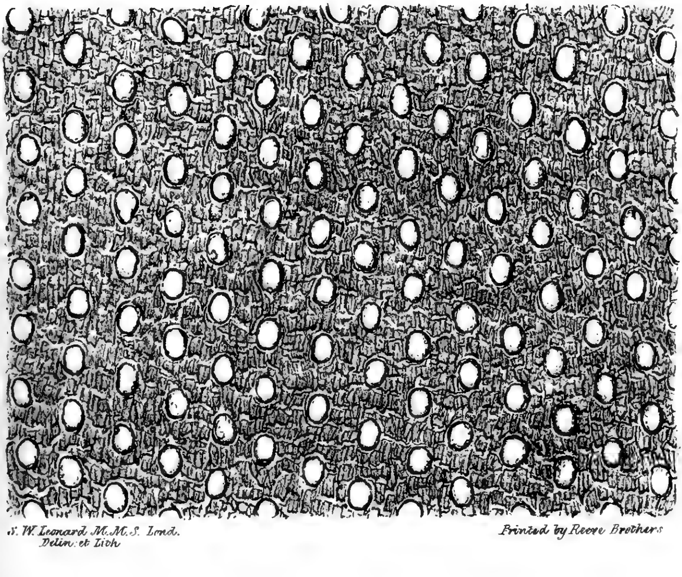

S. W. Leonard M.M.S. Lond.
Delin: et Lith

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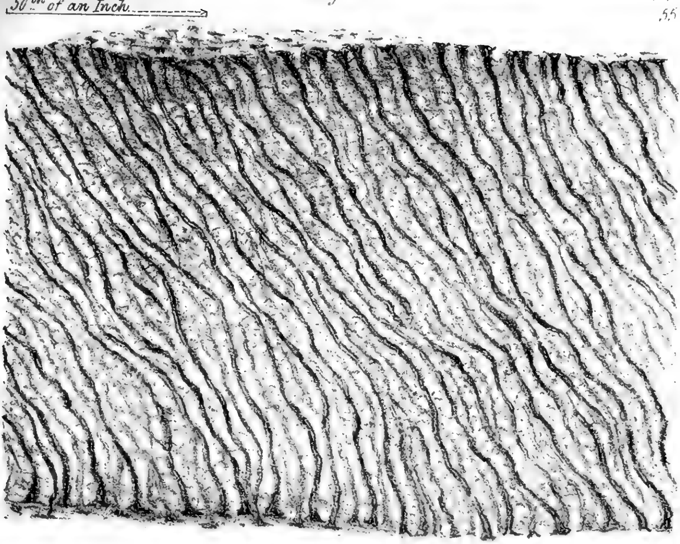
Fig: 37.



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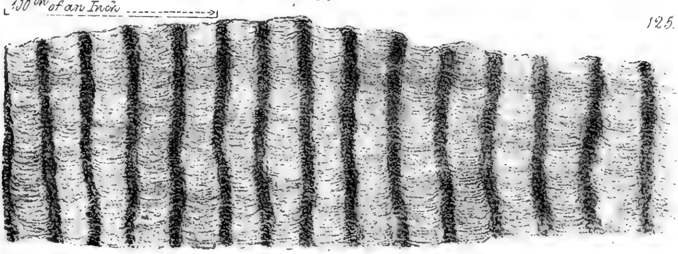

Fig: 39.

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Brit: Assoc: Report 1844.

Pl. 18

Fig 40.

200th of an Inch -------→ 250

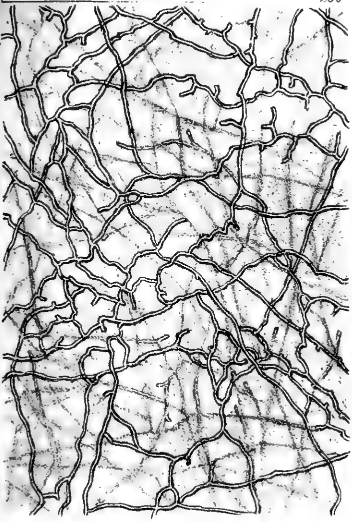


Fig 41.

250

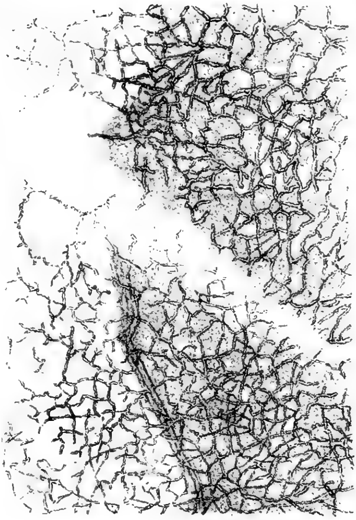
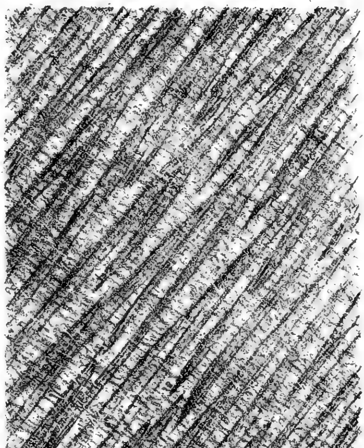


Fig 42

200th of an Inch -------→ 200.

Fig 43.

100th of an Inch -------→ 125



S. W. Leonard F.C.M.S. Lond:
Delin et Lith

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Pl. 19.

Fig: 44

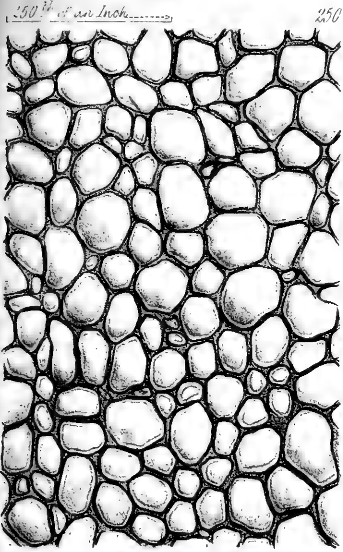


Fig: 45

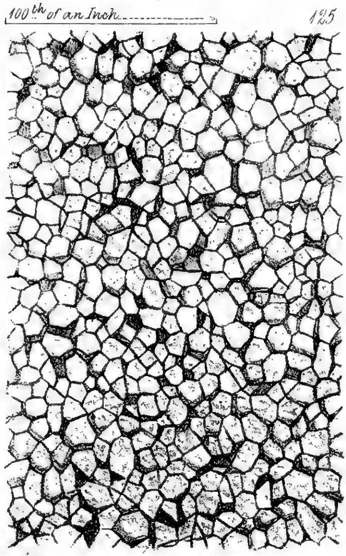


Fig: 46

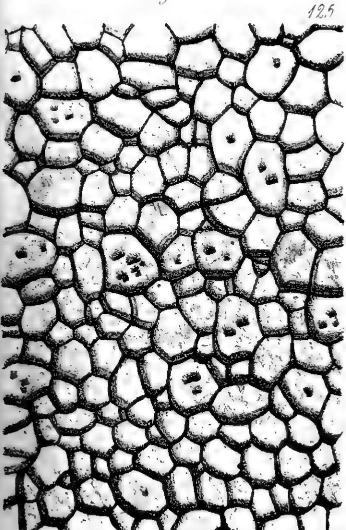
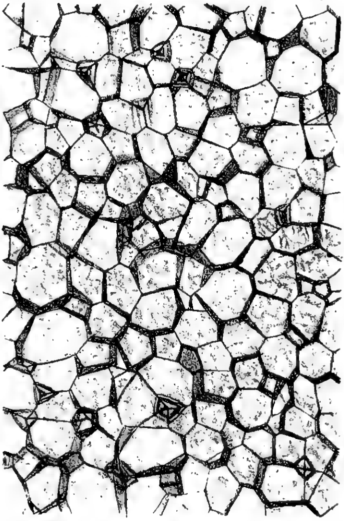


Fig: 47



S.W. Leonard. M.M.S. Lond
Delin et lith

Printed by Reeve Brothers

Fig: 48.

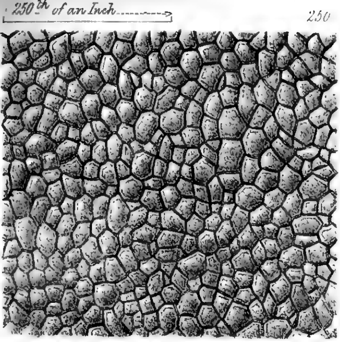


Fig: 50

Fig 49.

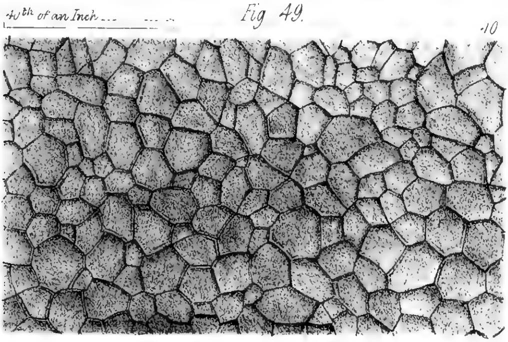


Fig: 51.

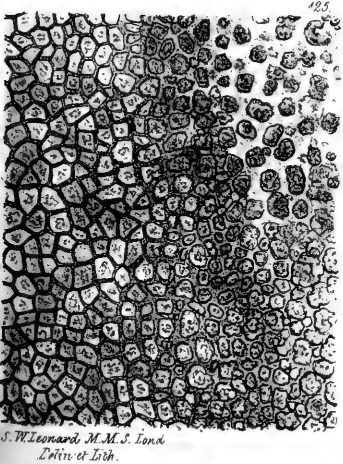
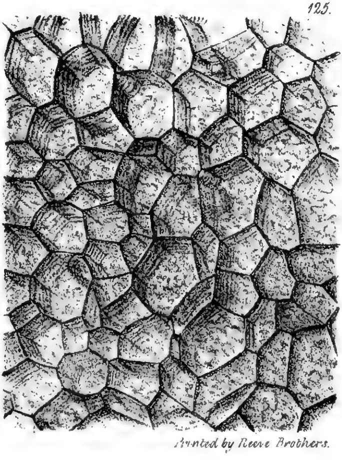


Fig 52



S. W. Leonard M.M.S. Lond
Delin et Lith.

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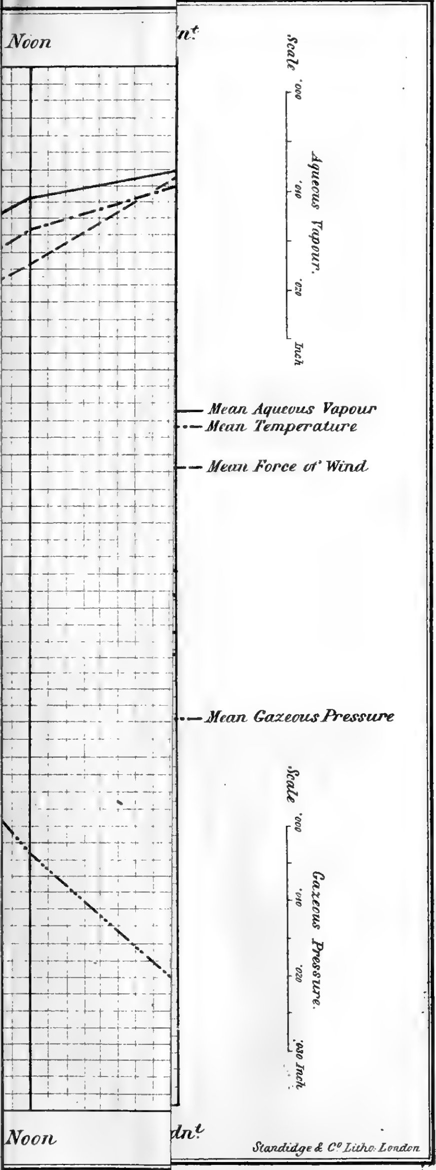
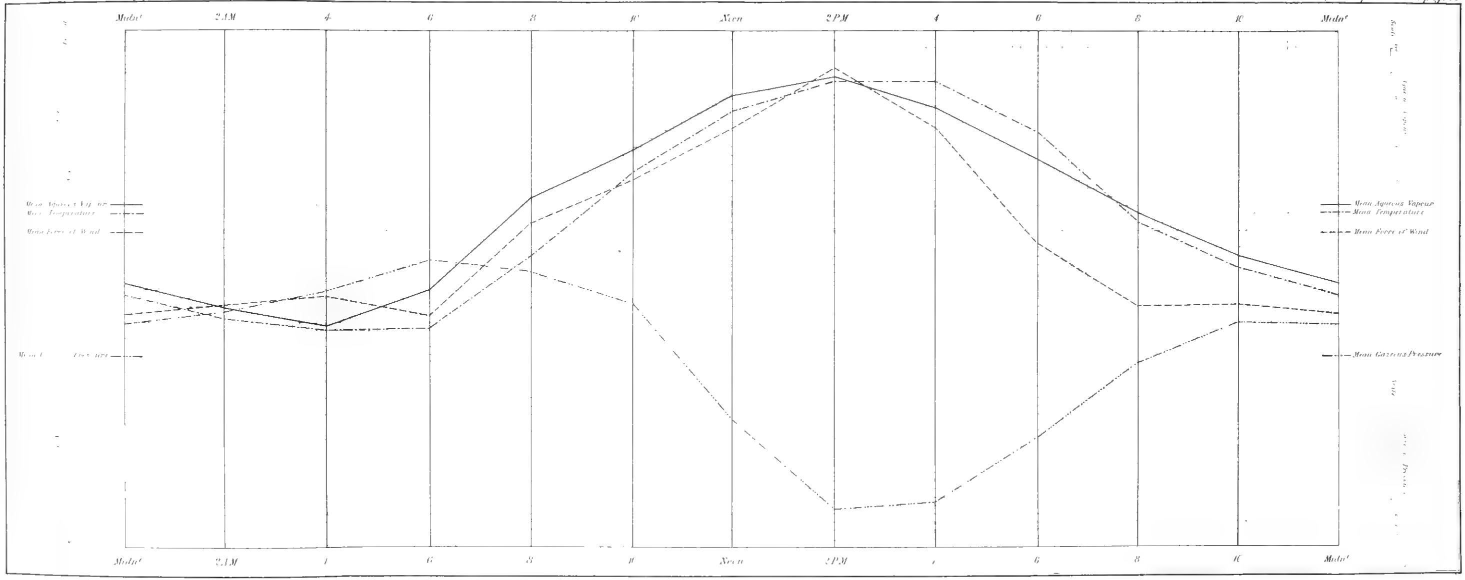
th Report. Plate 21. page 59.



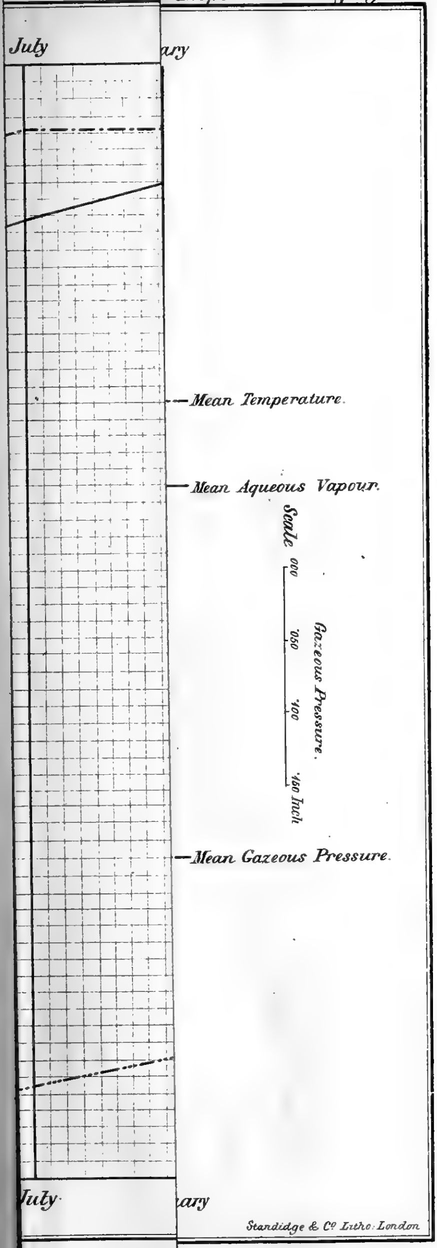
Standidge & Co Litho. London

Diurnal Variation of { The Temperature, The Force of the Wind; The Pressure of the Aqueous Vapour, The Pressure of the Gaseous Atmosphere } at Toronto



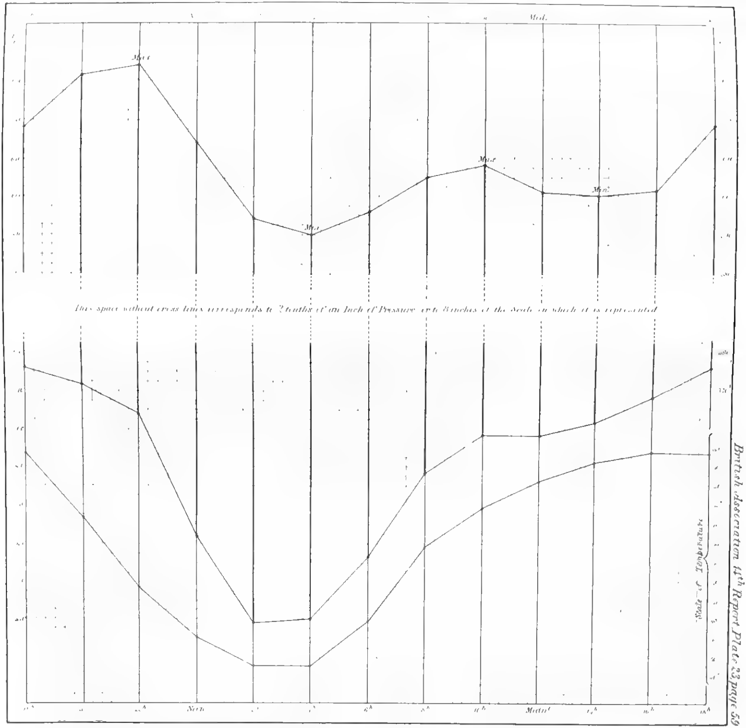
f the Aqueous V
f Two Years.

th Report Plate 22, page 59.



Standidge & Co Litho: London

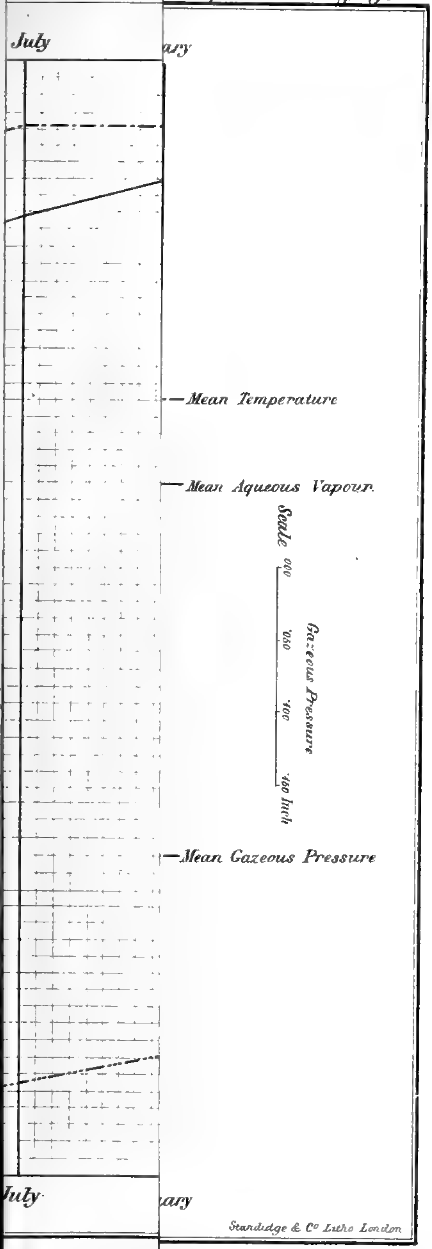
Plate illustrating the correspondence between the diurnal variations of the Temperature and of the Gaseous portion of the Atmosphere and the double procession of the Barometric pressure when the elastic force of the Vapour is superadded to the Gaseous Pressure



The upper Curve shows the Pressure indicated by the Barometer; the lines connecting the upper & middle Curves represent the elastic force of the Vapour; the dotted portion of each of these lines corresponds to ·2 of Vapour Pressure (or eight inches of the Scale on which the pressures are represented); the middle Curve denotes the residual pressure after the elastic force of the Vapour has been taken from the barometric Pressure; the detached Curve below represents the Temperature, and is inverted to shew the correspondence between the Curves of Temperature and Gaseous Pressure.

f the Aqueous V
f Two Years.

th Report Plate 22, page 59.

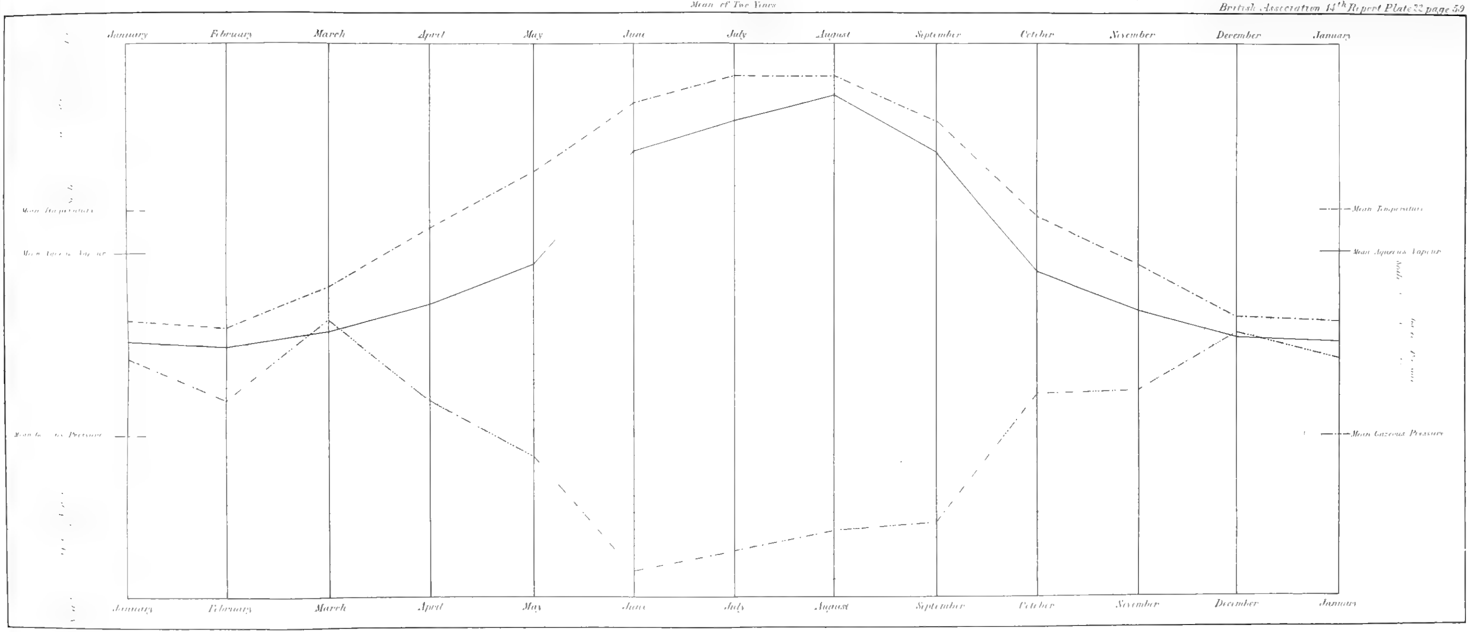


Standidge & Co Litho London

Annual Variation of ——— the Temperature ——— the Pressure of the Aqueous Vapour, ——— the Pressure of the Gaseous Atmosphere, at Toronto

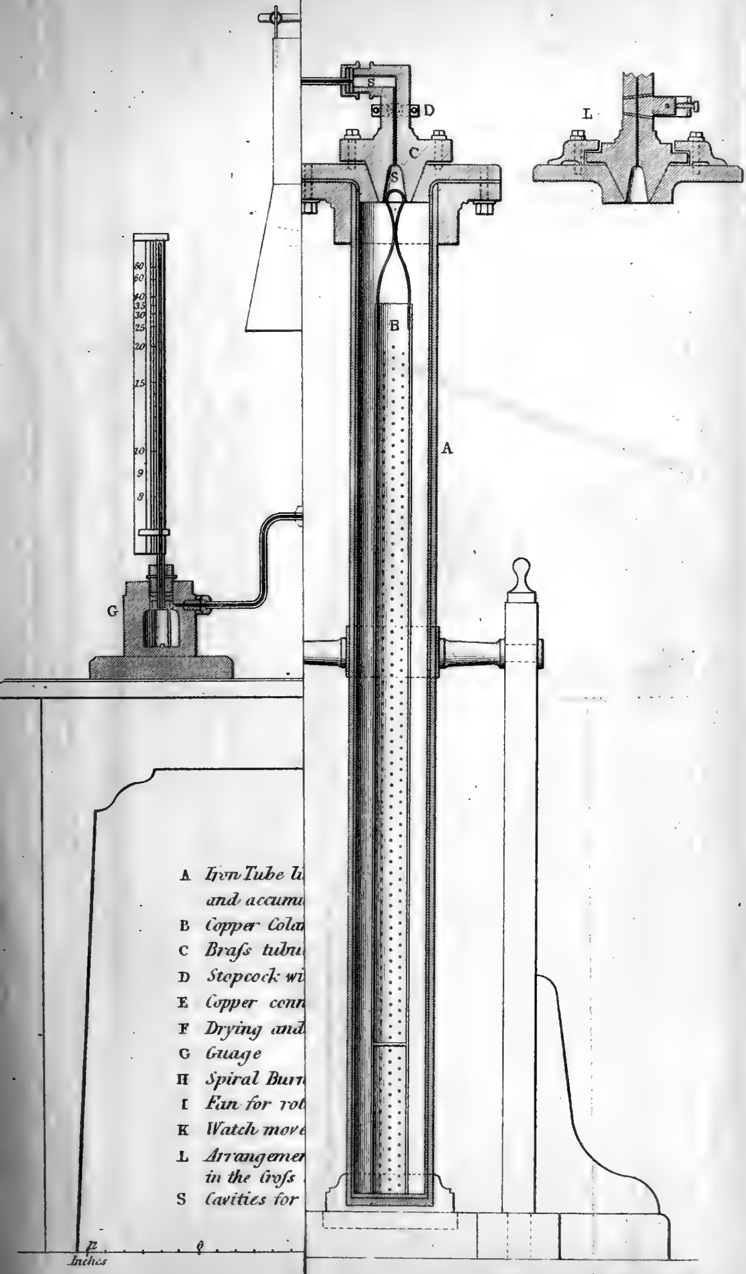
Mean of Two Years

British Association 14th Report Plate 22 page 59



port of the Brit. Aſsoc: for the Advancement of Science 1845.

Plate 24



A Iron Tube li
and accumu

B Copper Cola

C Braſs tubu

D Stopcock wi

E Copper conn

F Drying and

G Guage

H Spiral Burn

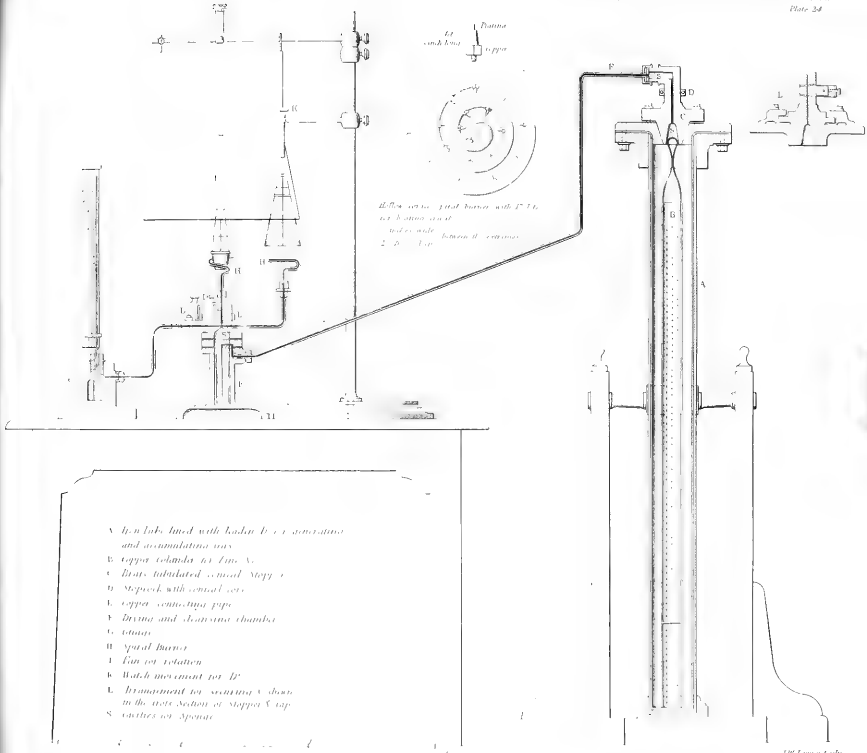
I Fan for rot

K Watch move

L Arrangemen
in the Croſs

S Cavities for

J.W. Lowry ſculp.



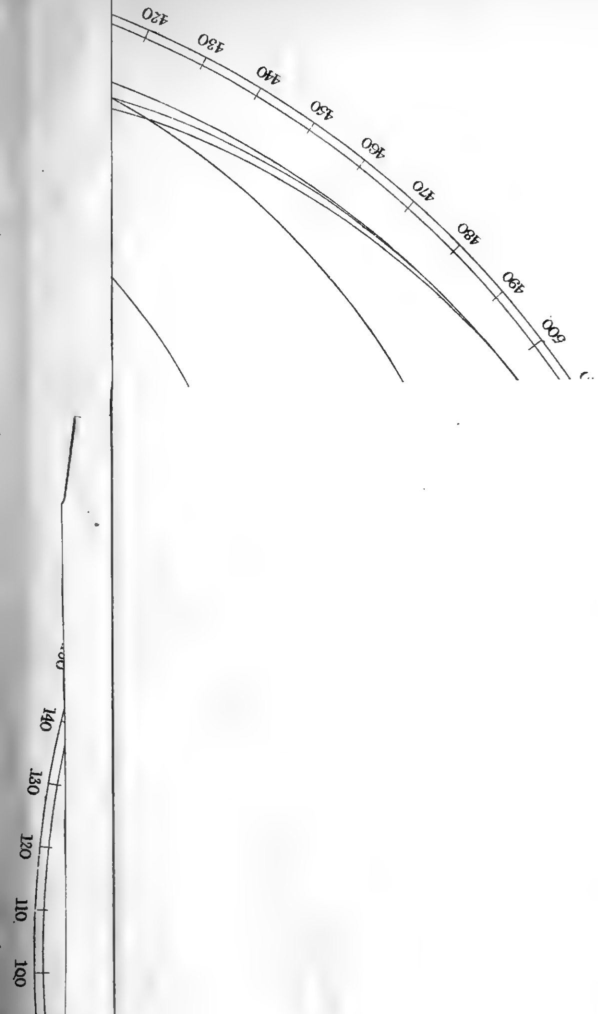
Hollow arm for spiral burner with 1/2 In [illegible]
for bottom [illegible]
[illegible] inches wide between the extremes
2 [illegible]

A Iron tube lined with leaden [illegible] generating and accumulating gas
B copper cylinder for Zinc &c
C Brass tubulated conical Stopper
D Stopcock with conical core
E copper connecting pipe
F Drying and cleansing chamber
G Gnomon
H Spiral Burner
I Fan for rotation
K Watch movement for D°
L Arrangement for securing C shown in the [illegible] Section of Stopper & cap
S cavities for Sponge

J.W. Lowry sculp.

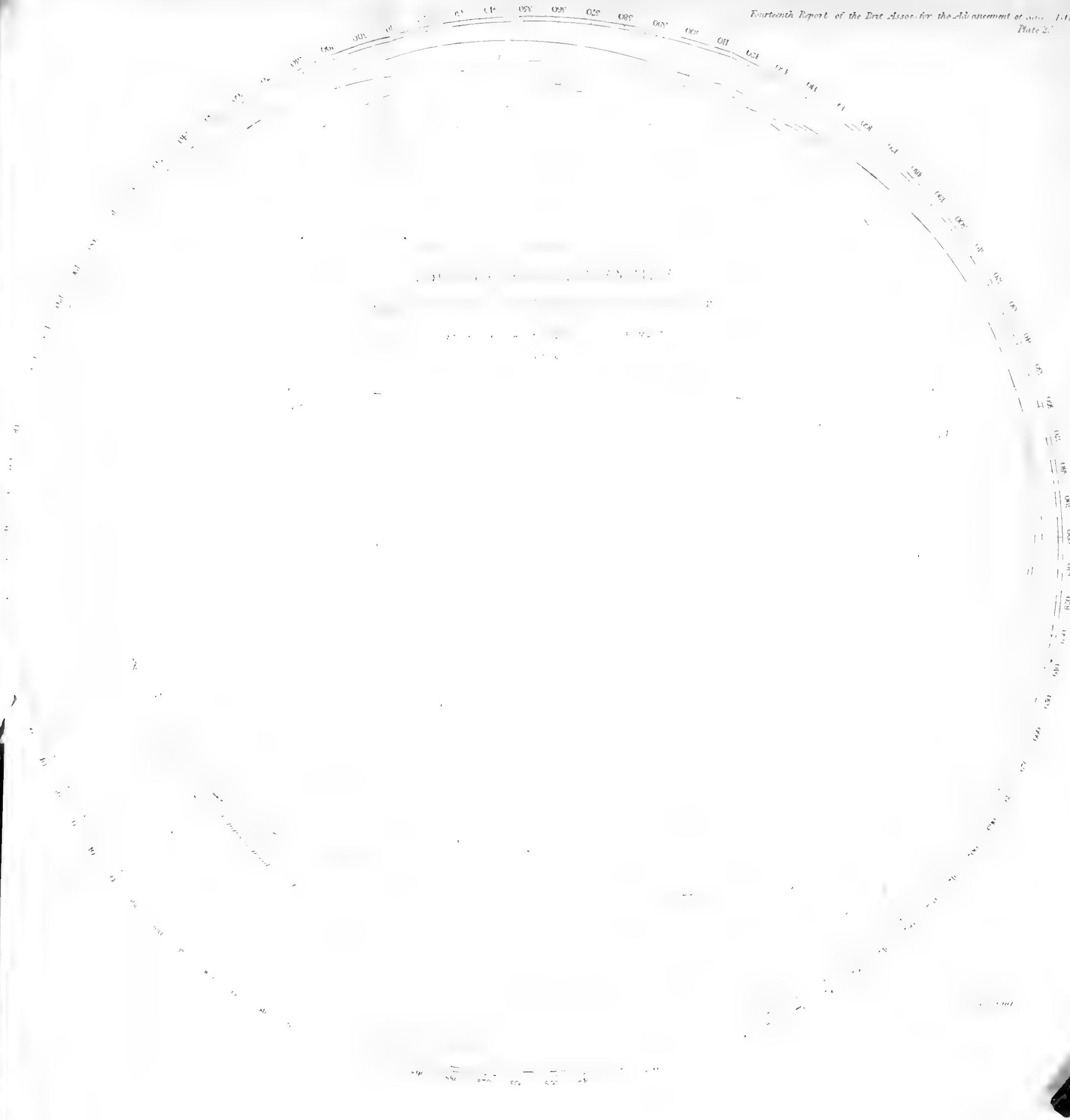
Fourteenth Report of the Brit: Assoc: for the Advancement of Science 1844

Plate 25



Fourteenth Report of the Brit. Assoc. for the Advancement of Science 1844

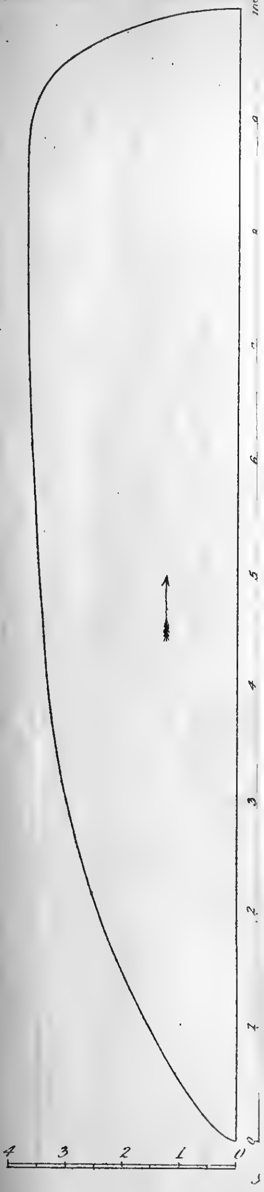
Plate 2.



CORNISH PUM

DIAGRAM (

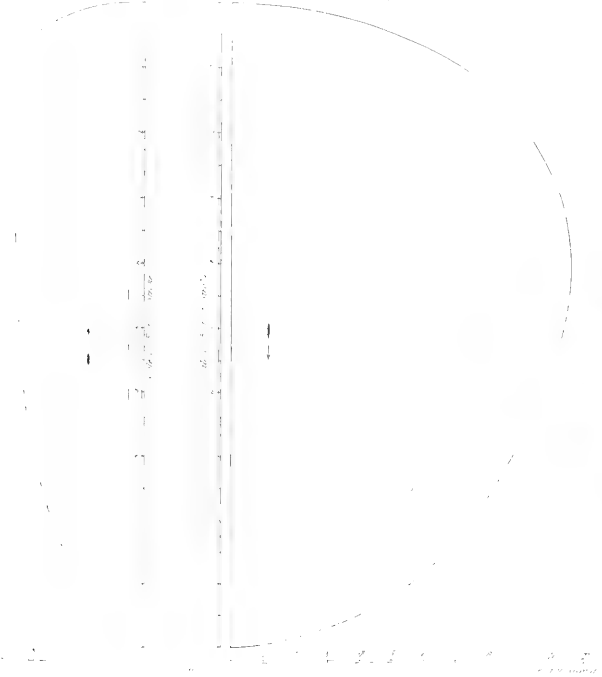
Out door Stroke (Piston ascendin



W. Pole, Del'n.

CORNISH PUMPING ENGINE — EAST LONDON WATERWORKS OLD FORD.

[illegible] OF THE VELOCITY OF THE PISTON AT DIFFERENT POINTS OF THE STROKE

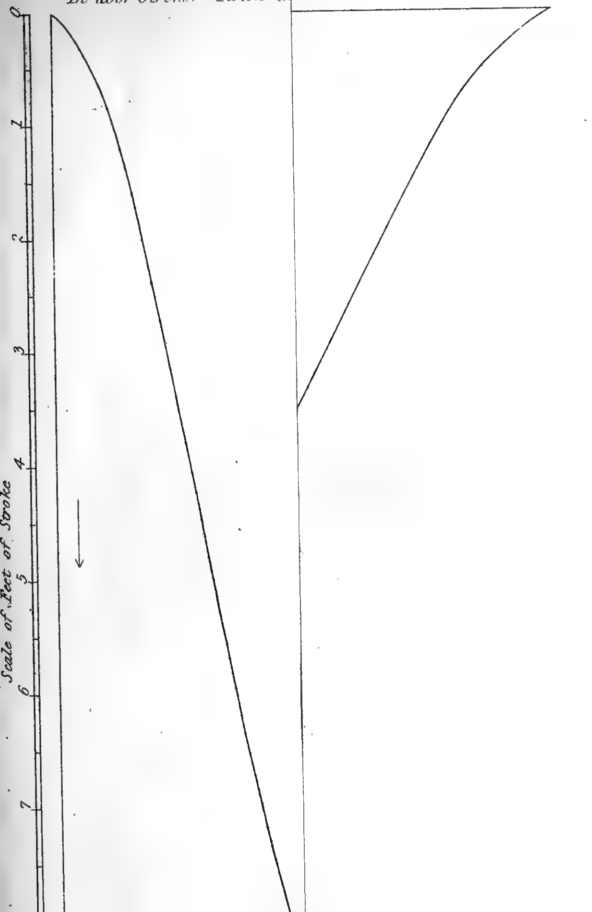


ssoc. for the advancement of Science 1844.

Plate 27.

COD.

In door Stroke. (Piston d



W. Pole. Delin.

J. W. Lowry. sculp.

[illegible] ENGINE [illegible] EAST LONDON WATERWORKS [illegible]

[illegible] ASCENDING & DESCENDING [illegible]

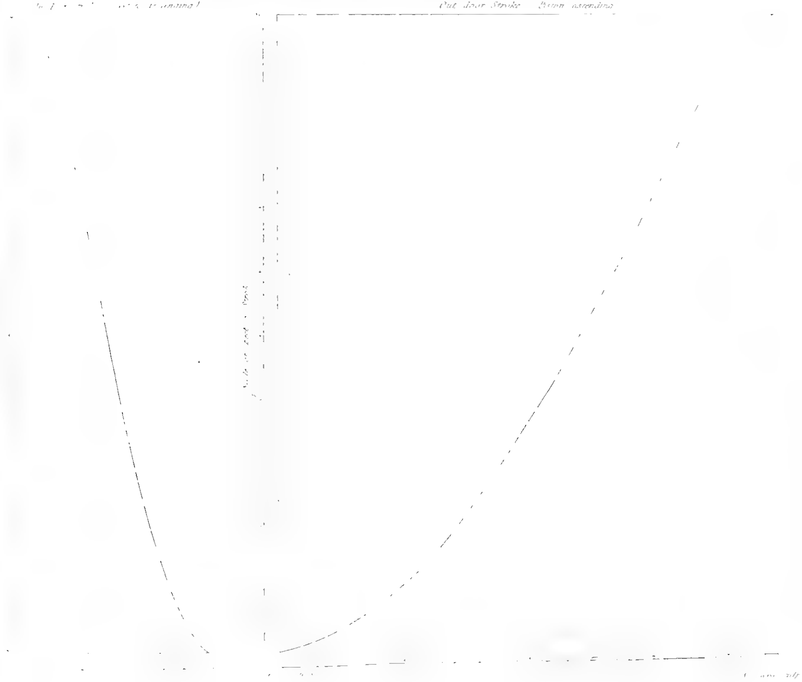
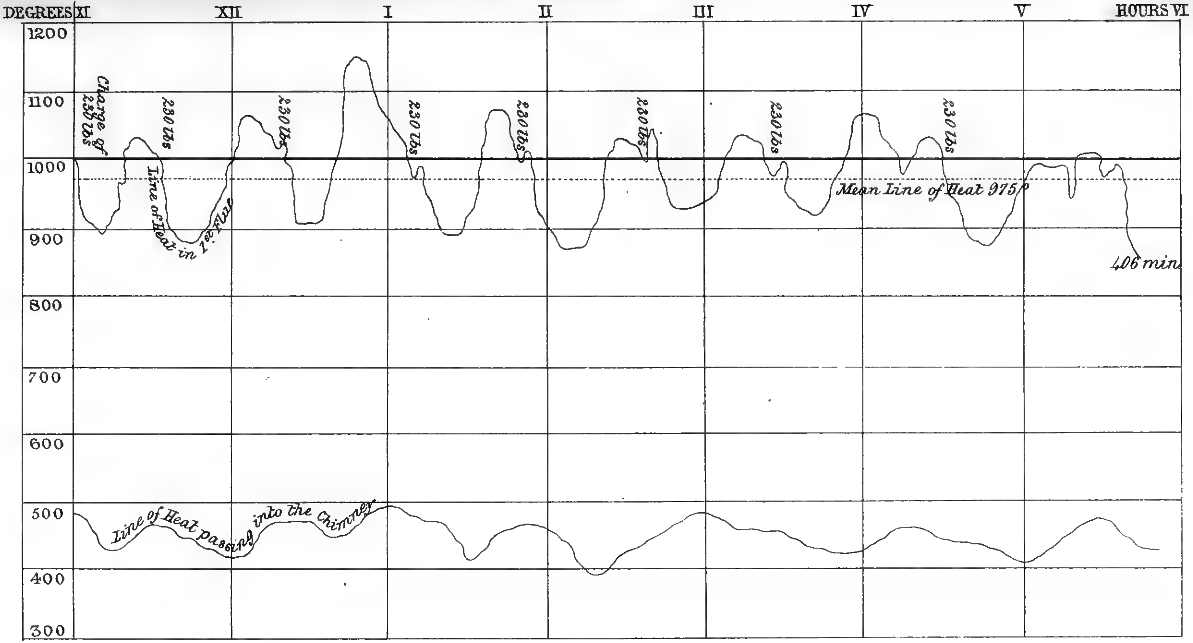
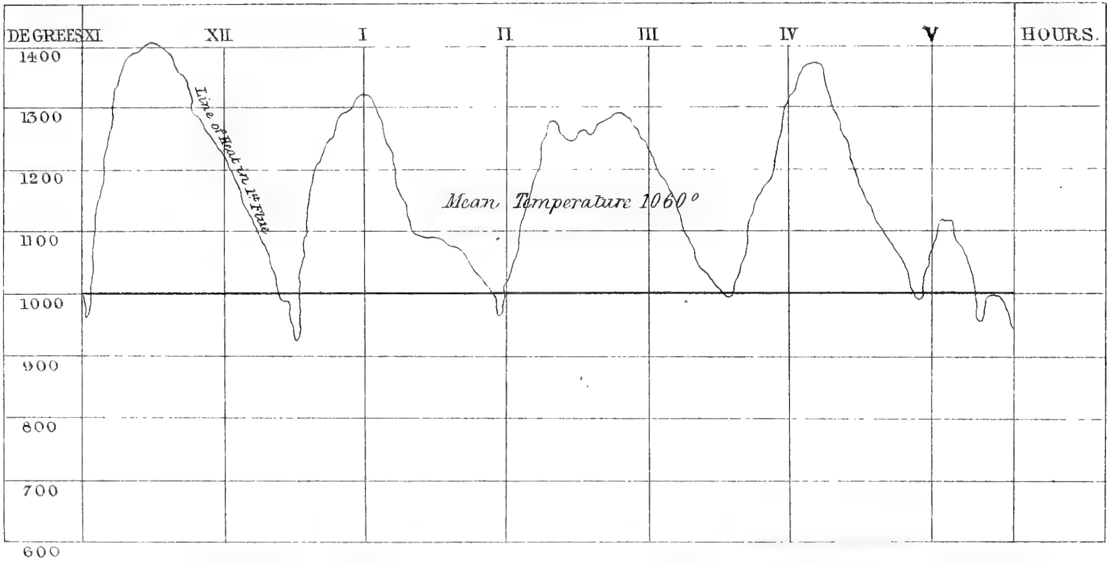


DIAGRAM XII.



In the above Diagram no Air was admitted, the Chimney emitting a dense black smoke. Water evaporated 930 Gallons = 5·05$^{\text{lbs}}$ of water to 1$^{\text{lb}}$ of coal.—

DIAGRAM XXX.



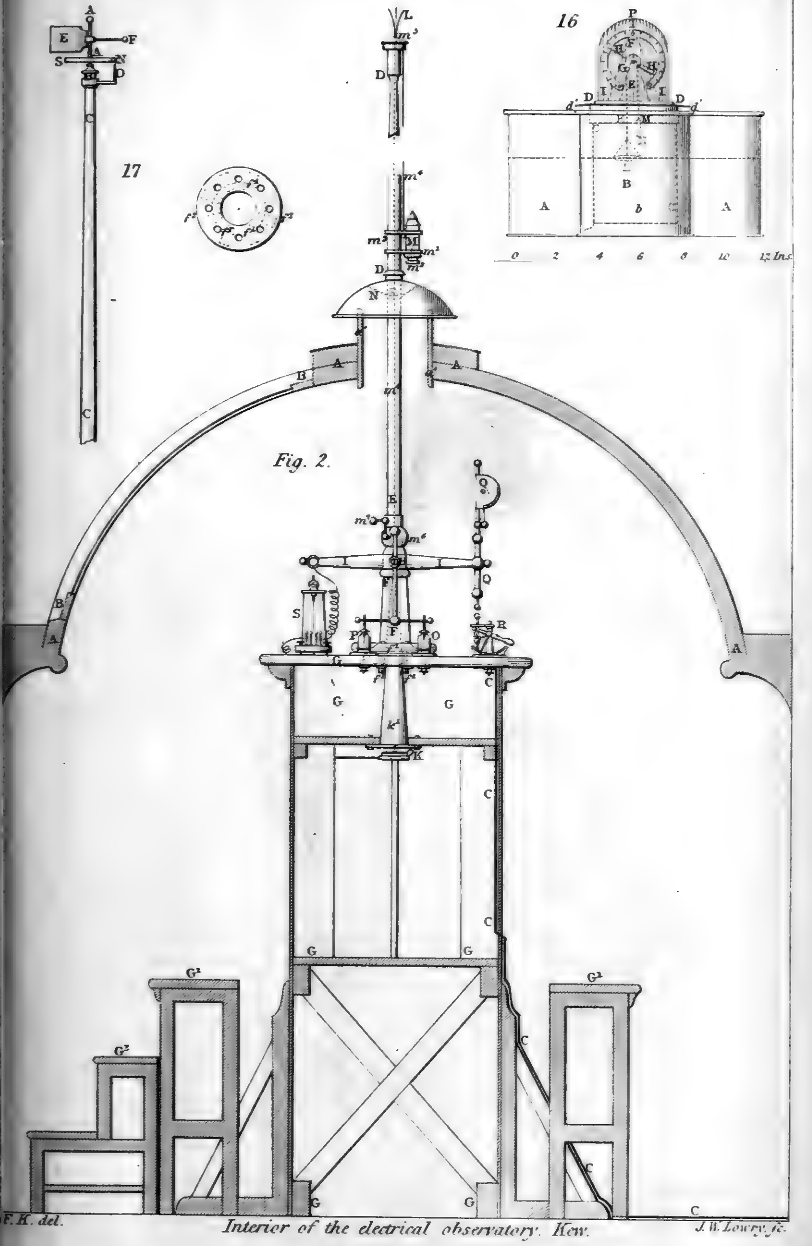
The air was regulated in this experiment until no smoke was produced. Quantity of water evaporated 1560 Gallons = 7·7 lbs of water to 1 lbs of coal.—

Fig. 1

F. R. del.

South & East Fronts of the Kew Observatory.

J. W. Lowry, fc.



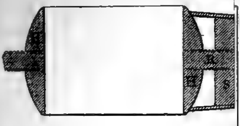
F. H. del.

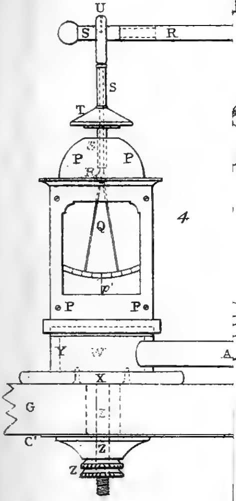
Interior of the electrical observatory. Kew.

J. W. Lowry. fc.

Plate 32

14th Report of the Brit. Assoc. for the Advanmt of Science 1844.





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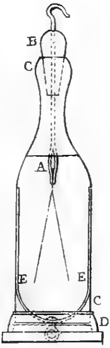

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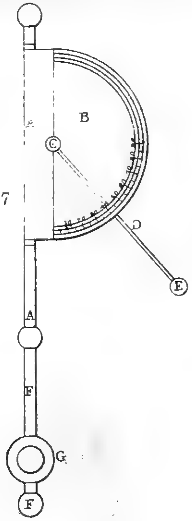

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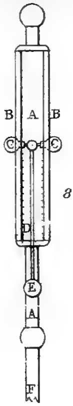

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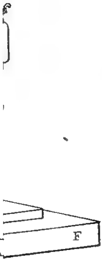
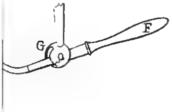
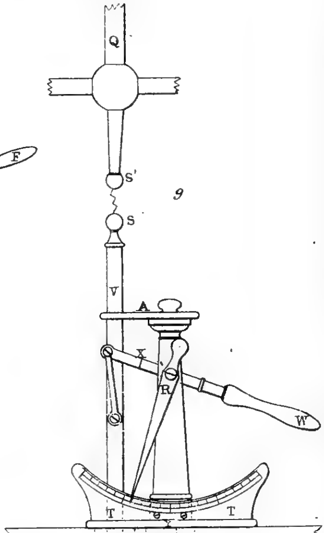


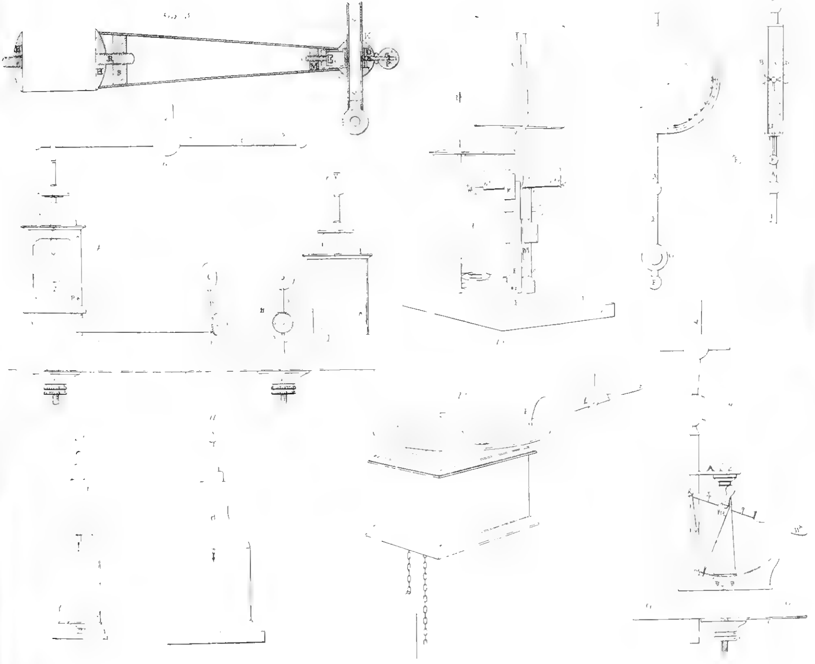




9

F.R. Del.

J.W. Lowry, fc.



F.

Apparatus of the Electrical Observatory &c. Kew

J.W. Lowry, fc.

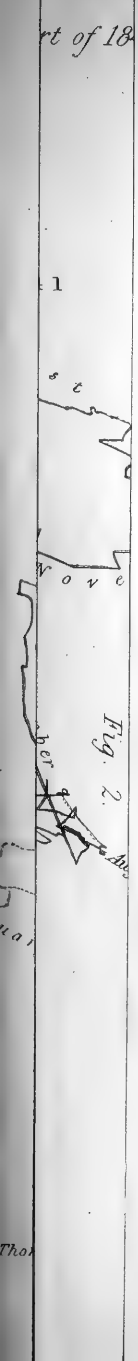
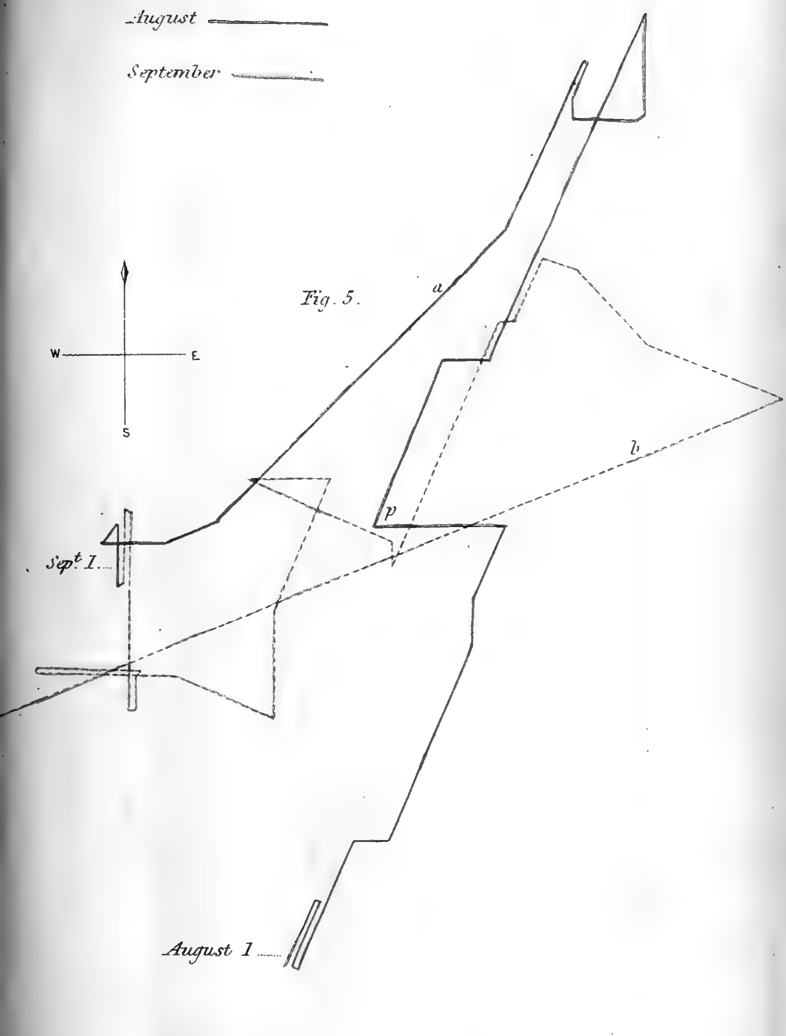


Fig. 2.

41.

1.

A Chart showing the general course of the Wind for the Years 1841, 1842, 1843, & part of 1844 as indicated by Whewell's Anemometer



J.W. Lowry fc.

Fig. 6.

1841

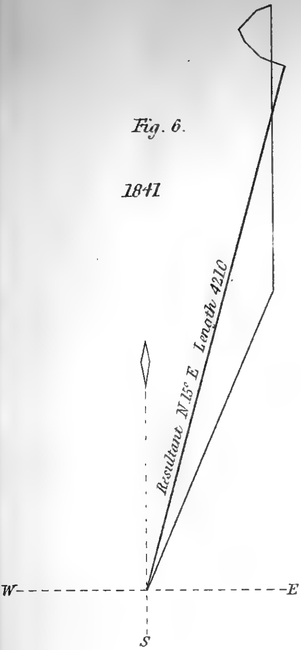


Fig. 7.

1842

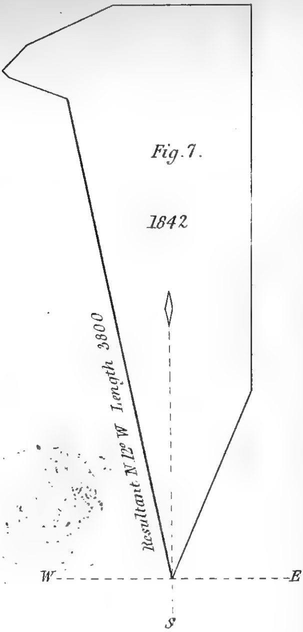


Fig. 8.

1843

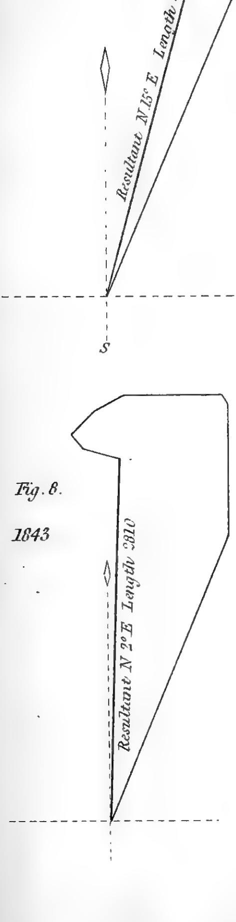
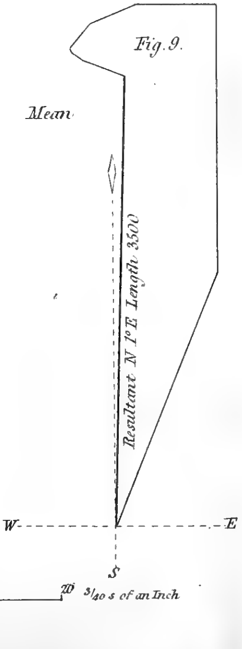


Fig. 9.

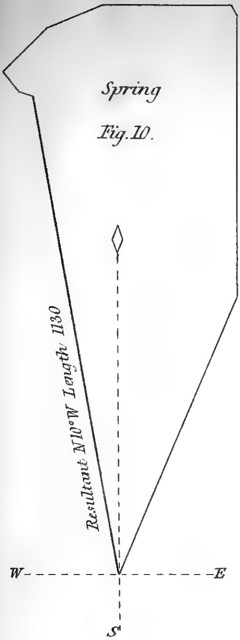
Mean



J. W. Lowry fc.

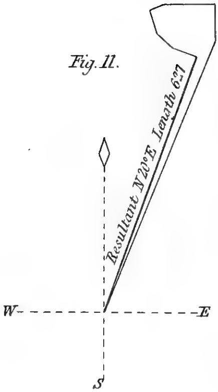
Spring

Fig. 10.



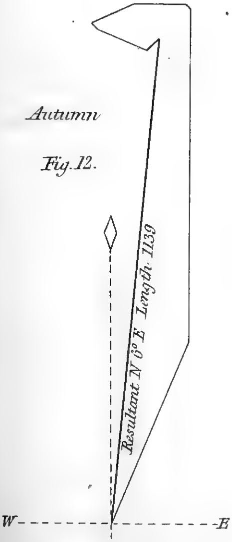
Summer

Fig. 11.



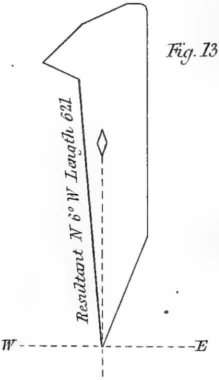
Autumn

Fig. 12.



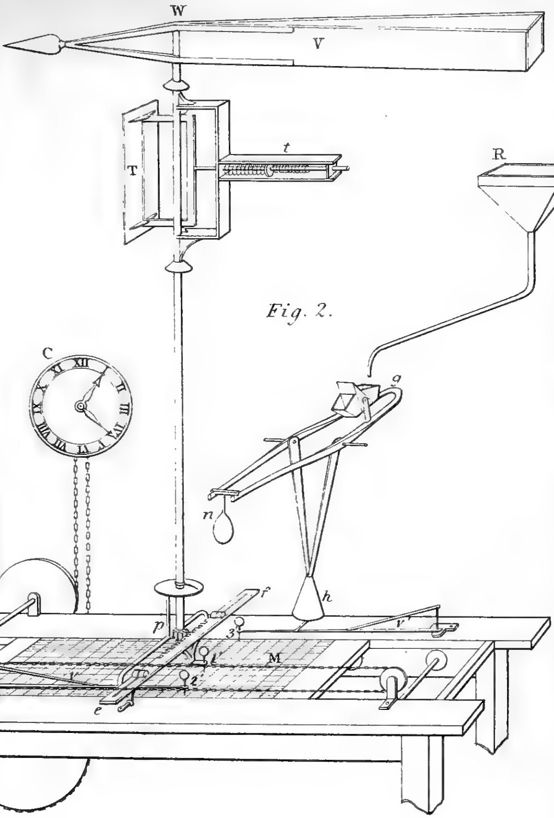
Winter

Fig. 13.



Scale 1/4 s of an Inch

J. W. Lowry fc.


W
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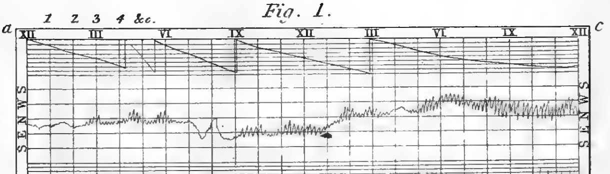
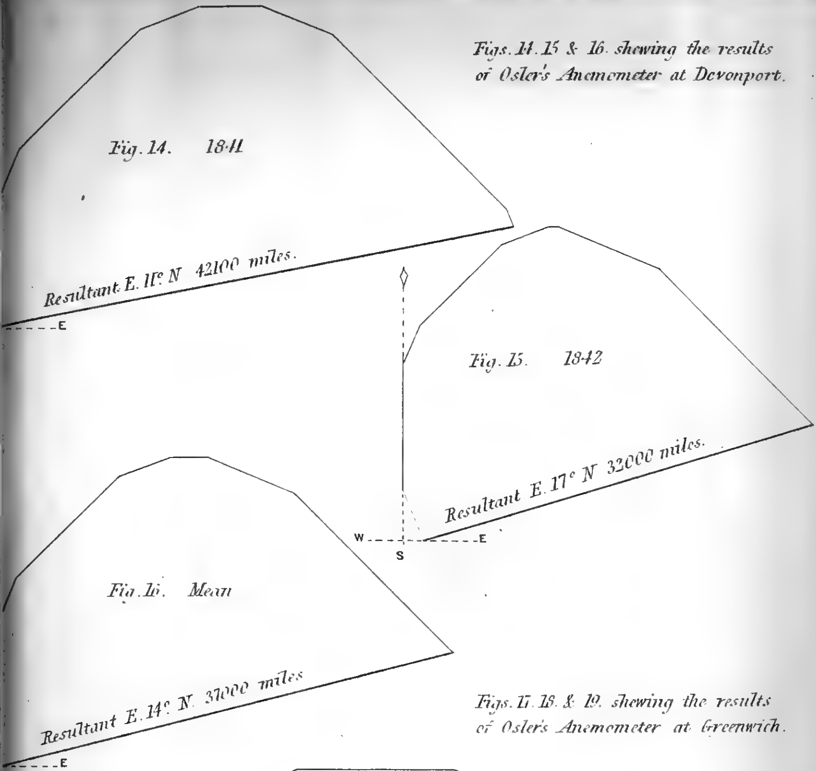
v
2
e
v'

Fig. 2.

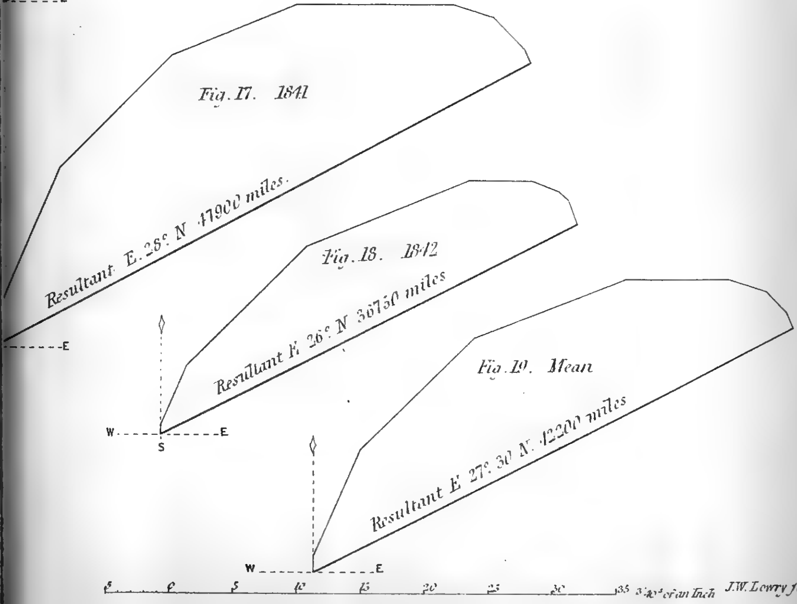
Fig. 1.


1 2 3 4 &c.
a
b
c
d
XII III VI IX XII III VI IX XII
S E N W S
S E N W S
XII III VI IX XII III VI IX XII

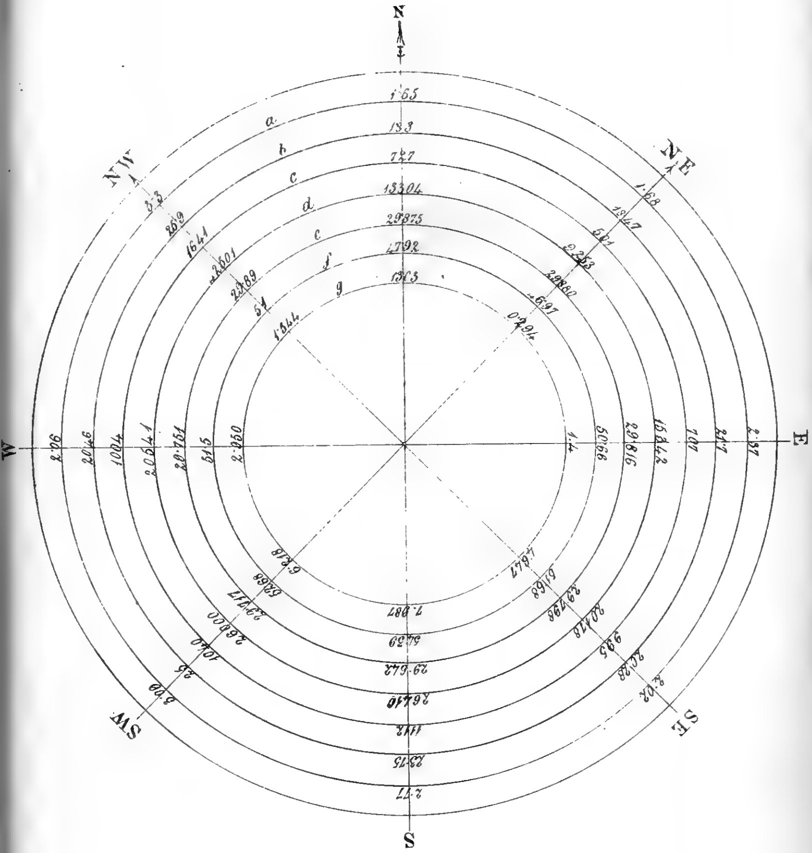
Figs. 14. 15 & 16. shewing the results of Osler's Anemometer at Devonport.



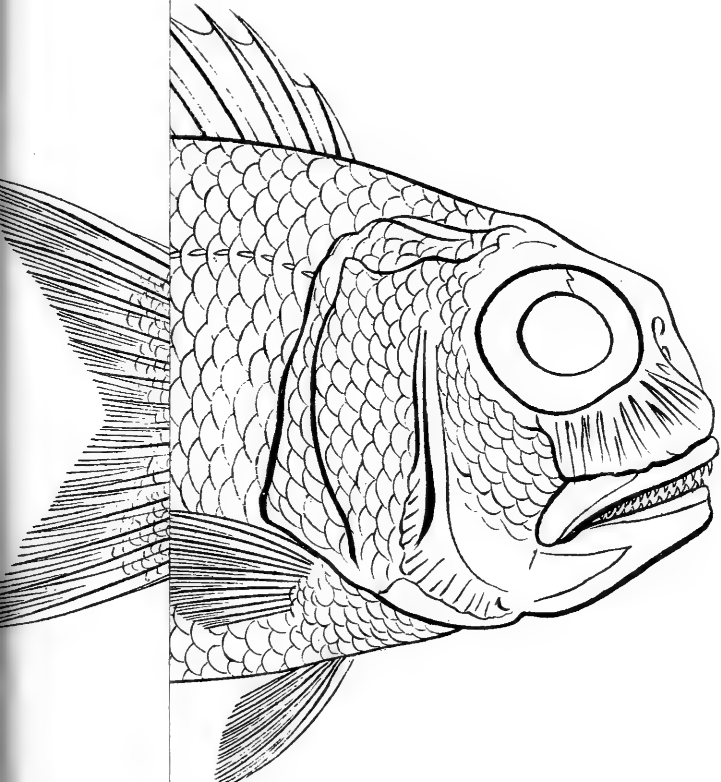
Figs. 17. 18. & 19. shewing the results of Osler's Anemometer at Greenwich.



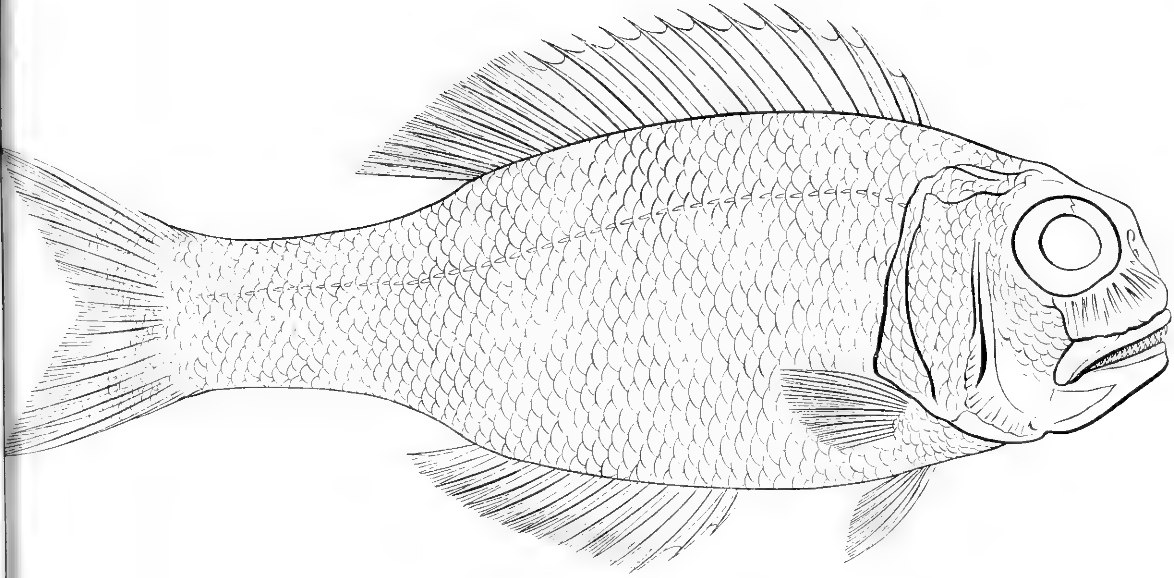
J.W. Lowry fc.



J Basire, Zinco:



J. Basire, lith.



Sciænurus Bowerbankii. (restored)

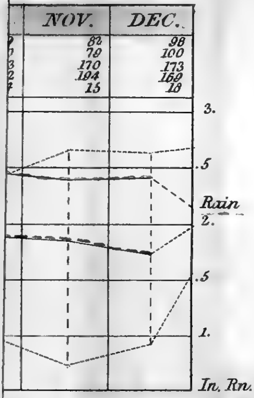
Sheppey.

J. Basire sc.

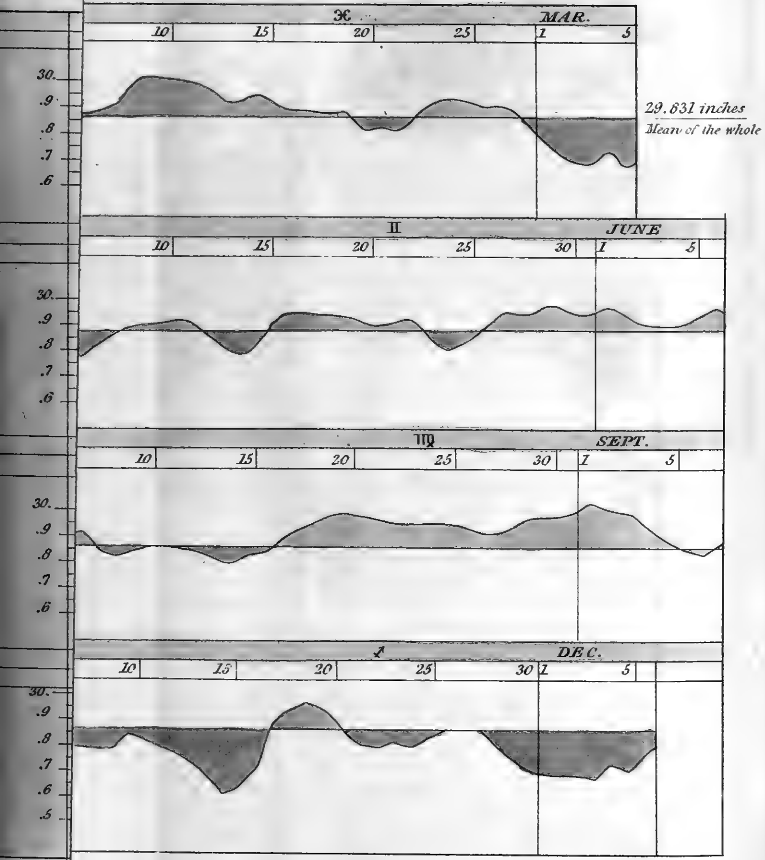
Fourteenth Report of the Brit. Assoc: for the Advancement of Science 1844.

Plate 41.

arometer 1813 — 30.



he Scale 1½ in. to the Inch.



uke Howar

J.W. Lowry fc.

DIAGRAM Nº I.

Monthly proportions of the Winds in Four Clafses, average depth of Rain average range and Mean of the Barometer 1813 . 30.

		JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
a	N E	109	77	105	118	144	132	79	95	114	99	82	98
b	E S	102	90	89	119	124	78	66	63	100	120	70	100
c	S W	130	112	152	116	123	122	100	156	161	153	173	173
d	W N	180	172	191	168	115	190	230	237	151	172	191	169
e	Var &.	37	23	21	19	22	18	23	7	11	11	15	18

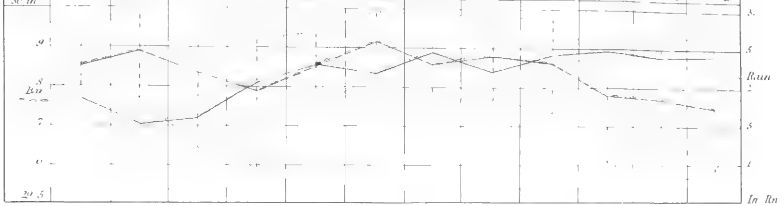
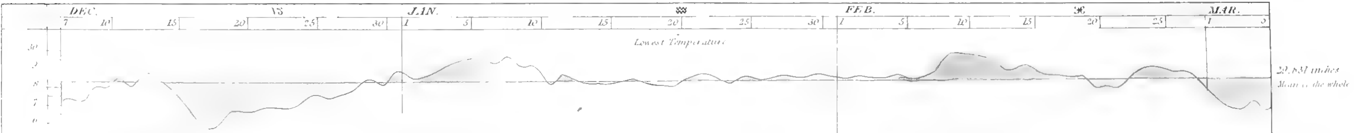
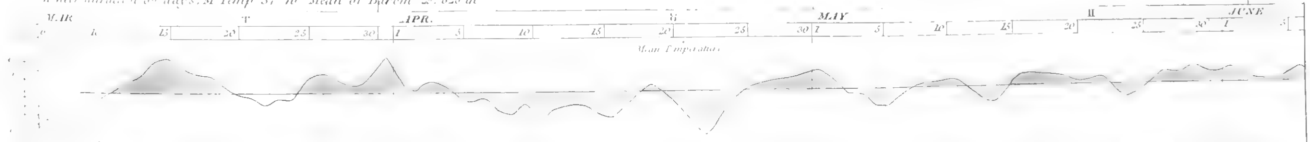


DIAGRAM OR CHART Nº 2

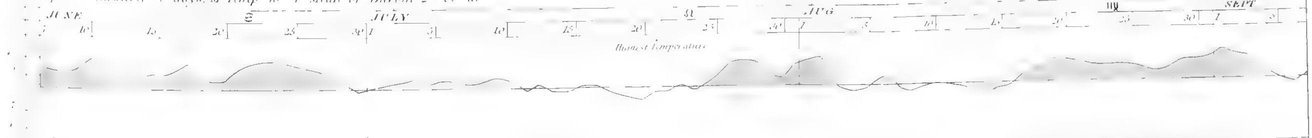
Mean Year of the Barometer showing its daily average height thro' the several Seasons &c from 1813 30 Climate of LONDON. The scale 1½ in to the Inch.



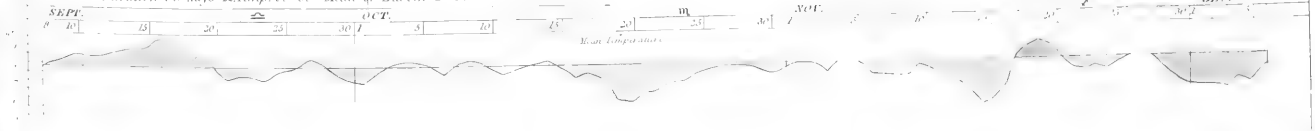
Winter duration 89 days, M Temp 37 76° Mean of Baromr 29. 828 in



Spring duration 93 days, M Temp 48 91° Mean of Barom 29 835 in



Summer duration 93 days M.Temp. 60 66° Mean of Barom 29 879 in

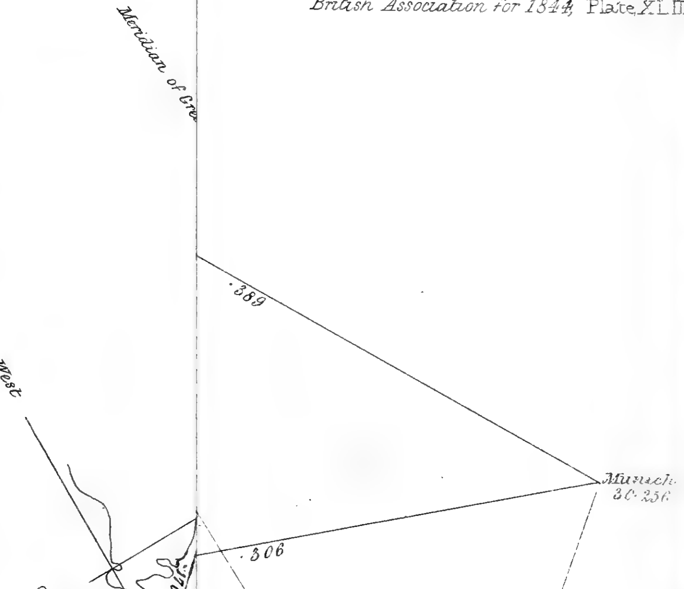


Autumn duration 90 days, M Temp 49 37° Mean of Barom. 29.782 in Climate of LONDON.

L. Howard F.R.S. invenit et del.

J.D. [illegible] sc.

British Association for 1844, Plate XLII.



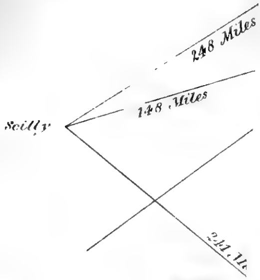
J. Basire, Zinco.

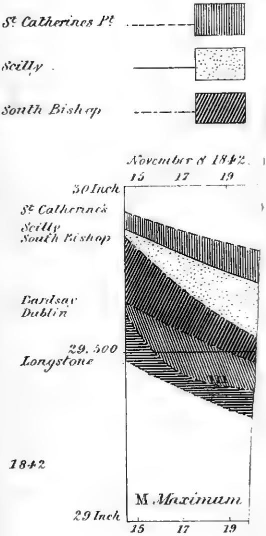
1842.
Nov. 9. 3. m. Minimum.

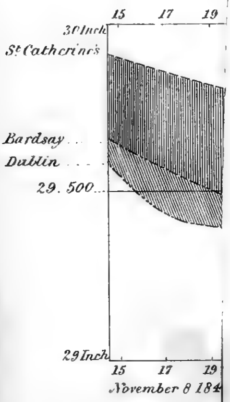
British Association 4 - 1844 Plate XLII

1842
Nov 9 3 . m Minimum

Fig. 1.







9.500
sels

Fig 1

Fig 2

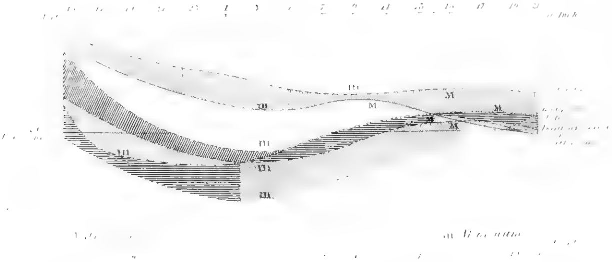
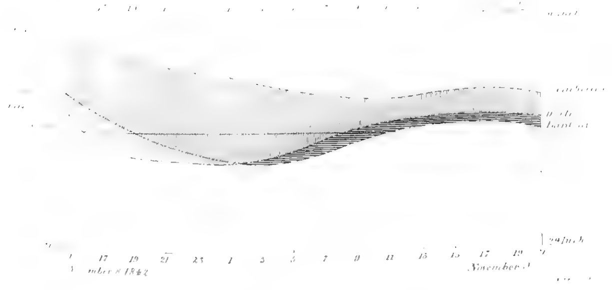
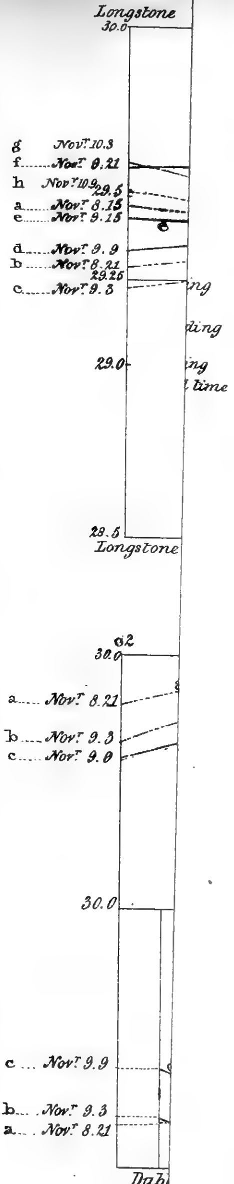


Fig 3





9.500
sels

J. Basire, Zinco

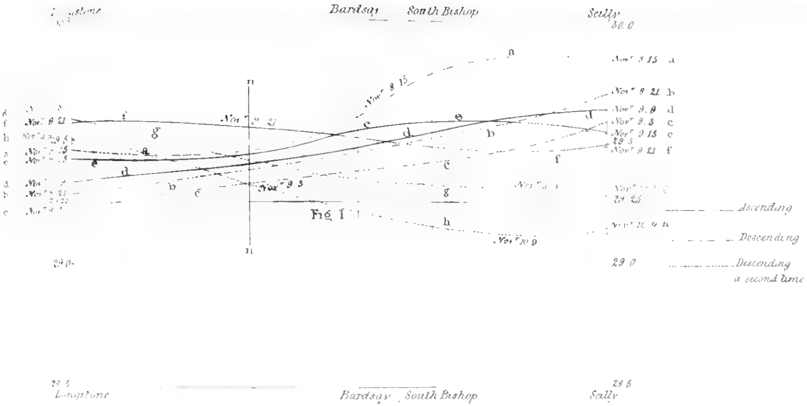


Fig 1

Fig 2

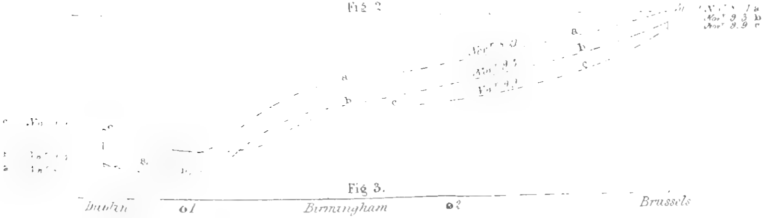


Fig 3.

Sections of Atmospheric Pressure.

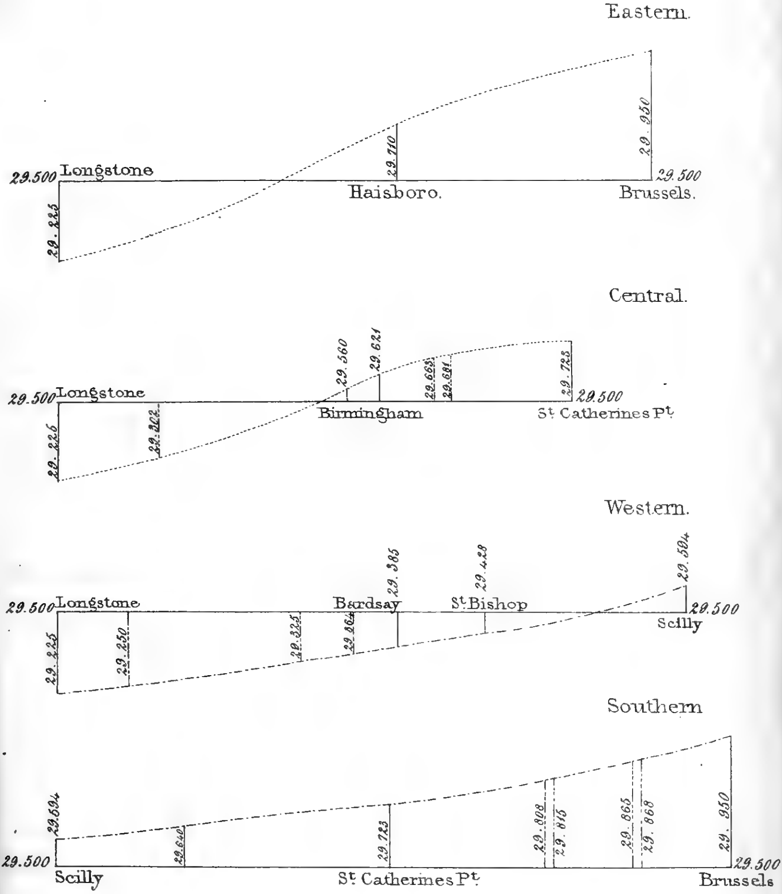
Fig 1. *Scilly, South Bishop, Bardsay Island, Longstone*

Fig 2. *Geneva, Brussels*

Fig 3. *Brussels, Birmingham, Dublin*

SECTIONS OF ATMOSPHERIC WAVES.

Sheet 1.



Sections exhibiting the distribution of Pressure across England and along its Eastern, Western, and Southern Coasts on November 9th 1842 at 3.P.M.

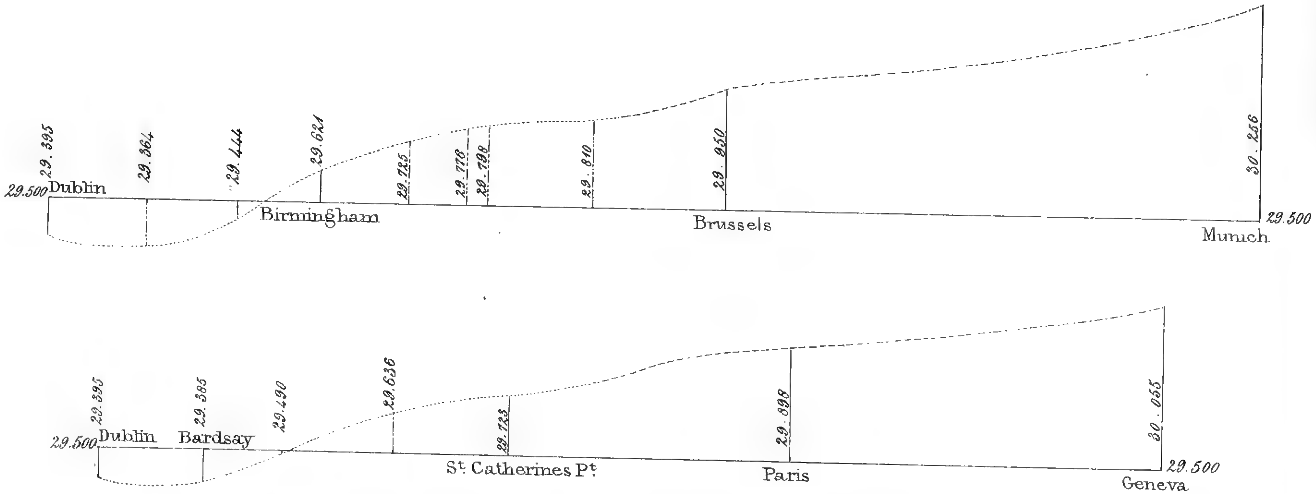
The observed ordinates are shewn thus ————————

Those interpolated from the intersections of Cross Sections — — — — — —

Wave having its Posterior slope towards Longstone ....

Normal wave (supposed) —·—·—·—·—

Sheet 2.



Sections exhibiting the distribution of Pressure over the area included by Dublin. Munich, and Geneva on Novr 9. 1842. 3 P.M.

Observed Ordinates ———— *Interpolated Ordinates* —·—·—

Wave with its Posterior Slope to Dublin ·········

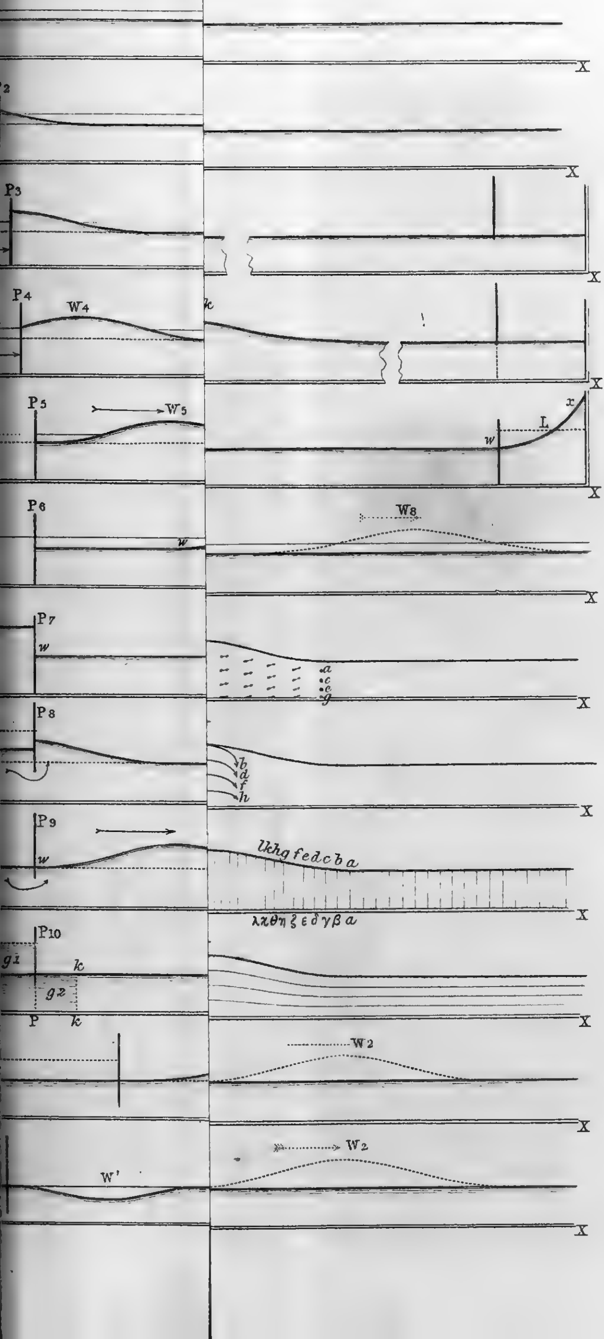
Wave preceding this ·········

Supposed Normal Wave. — — — — —

—·—·—·—

For the pressure between St Catherines Point and Birmingham, see the central curve of the English Distribution.

Plate 47.



X
2
X
P3
X
P4
W4
X
P5
W5
x
L
w
X
P6
w
W8
X
P7
w
a
c
e
g
X
P8
b
d
f
h
X
P9
w
lkhgfedcba
λκθηζεδγβα
X
P10
g1
k
g2
P
k
X
W2
X
W2
W'
X

WAVES_Order I. The Great Wave of Translation

British Association for 1844
Plate 47.

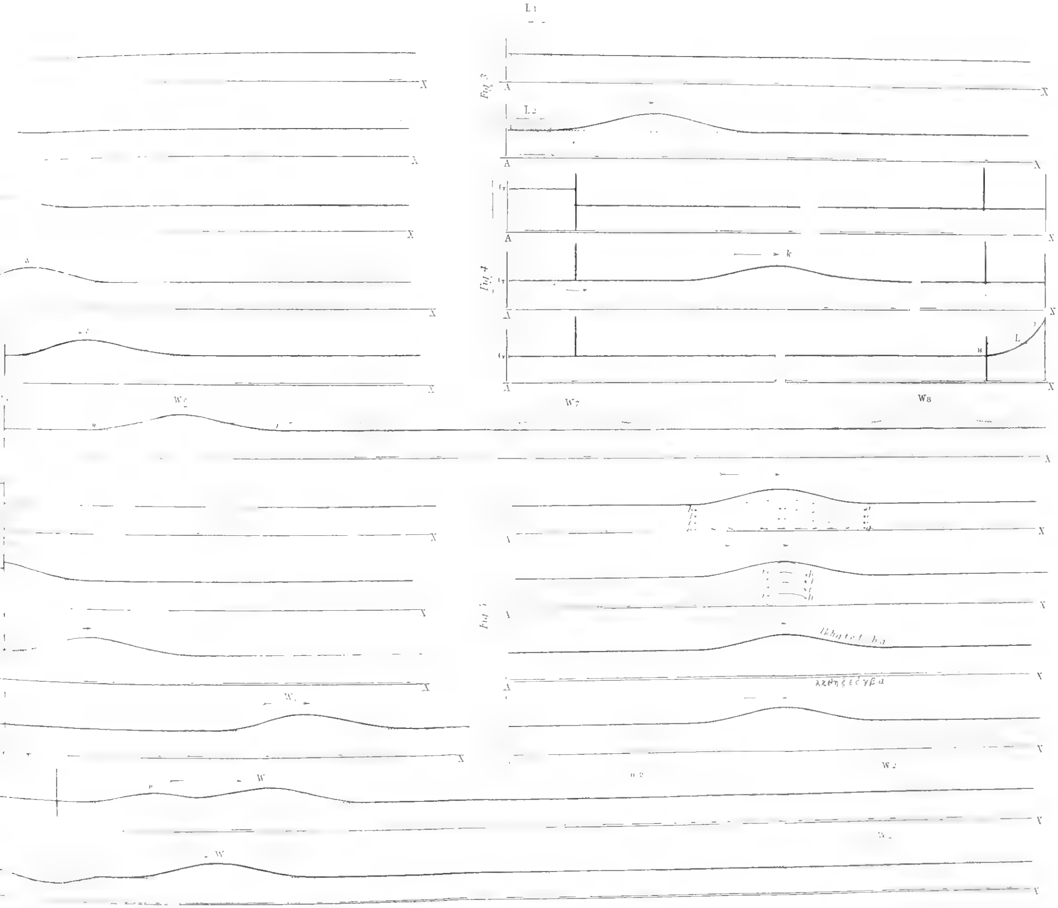


Fig. 3.

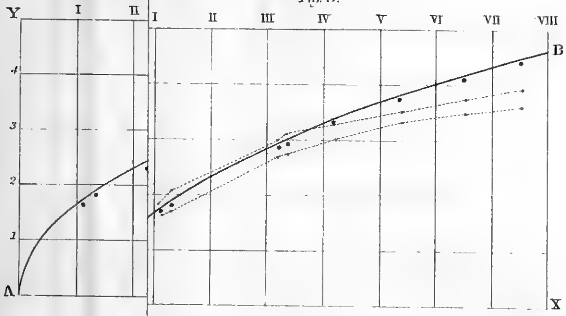


Fig. 4.

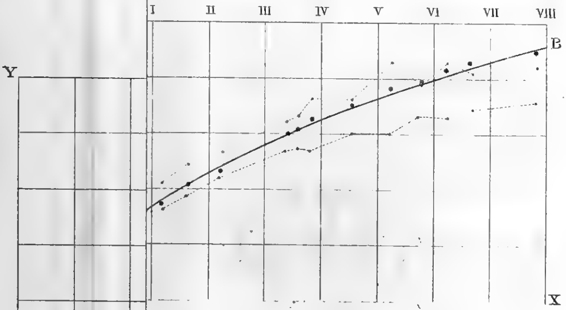


Fig. 7.

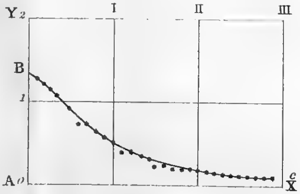
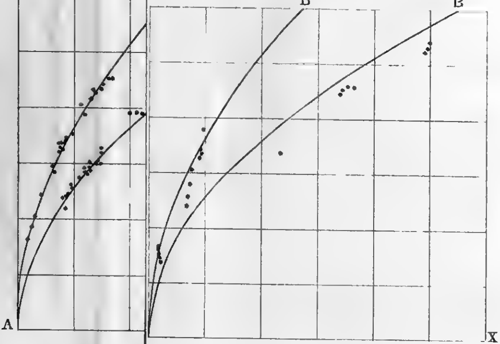
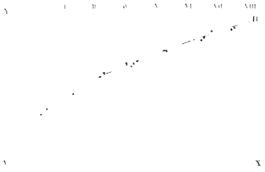
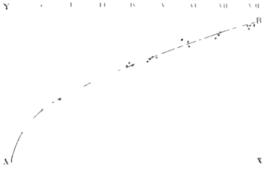
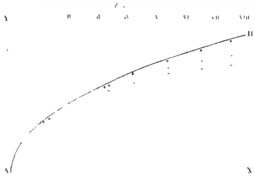


Fig. 5.

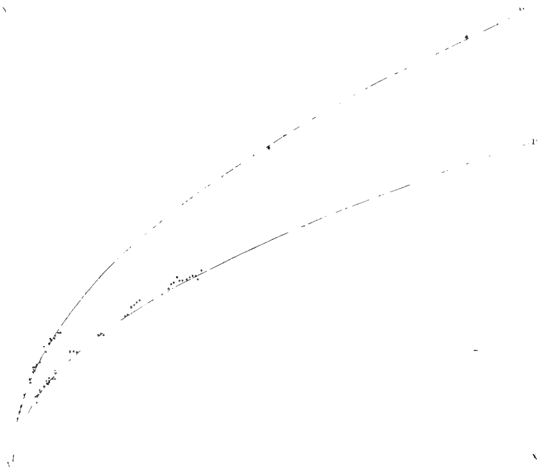


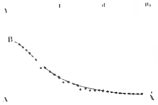

Y
I
II
IV
V
VI
VII
VIII
B
X


Y
I
II
IV
V
VI
VII
VIII
B
A
X


Y
II
III
IV
V
VI
VII
VIII
B
A
X

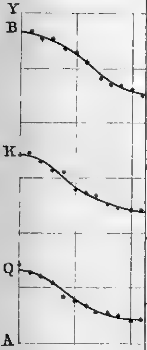

Y
I
II
III
V
VI
VII
VIII
B
A
X


Y
B
B
A
X


Y
I
II
III
B
A
X


Y
B
B
A
X

Effects of form of Channel.



. 3 .

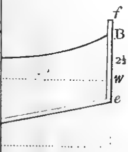
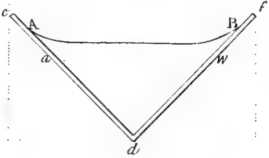


Fig. 4.



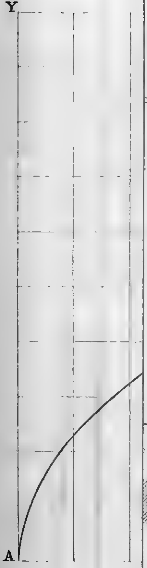


Fig. 5.

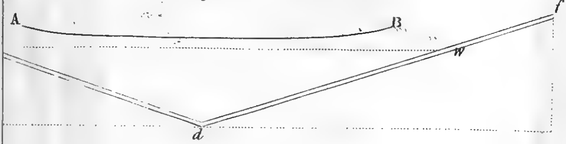


Fig. 6.

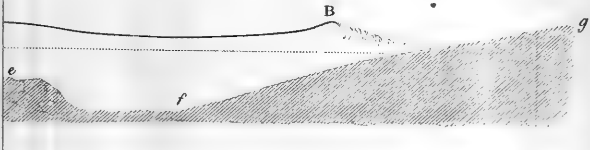
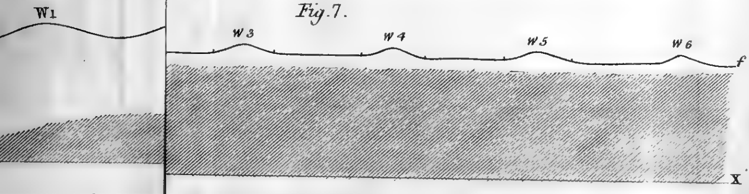
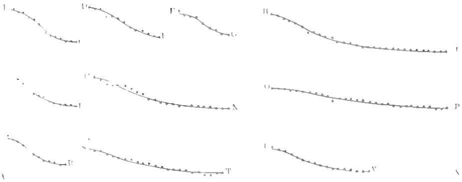


Fig. 7.

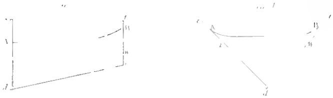


Reduction of the Experiments

Fig. 2



Limits of form of channel



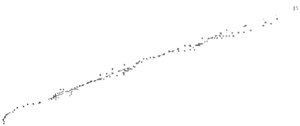
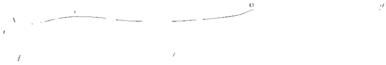
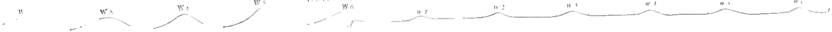


Fig. 5

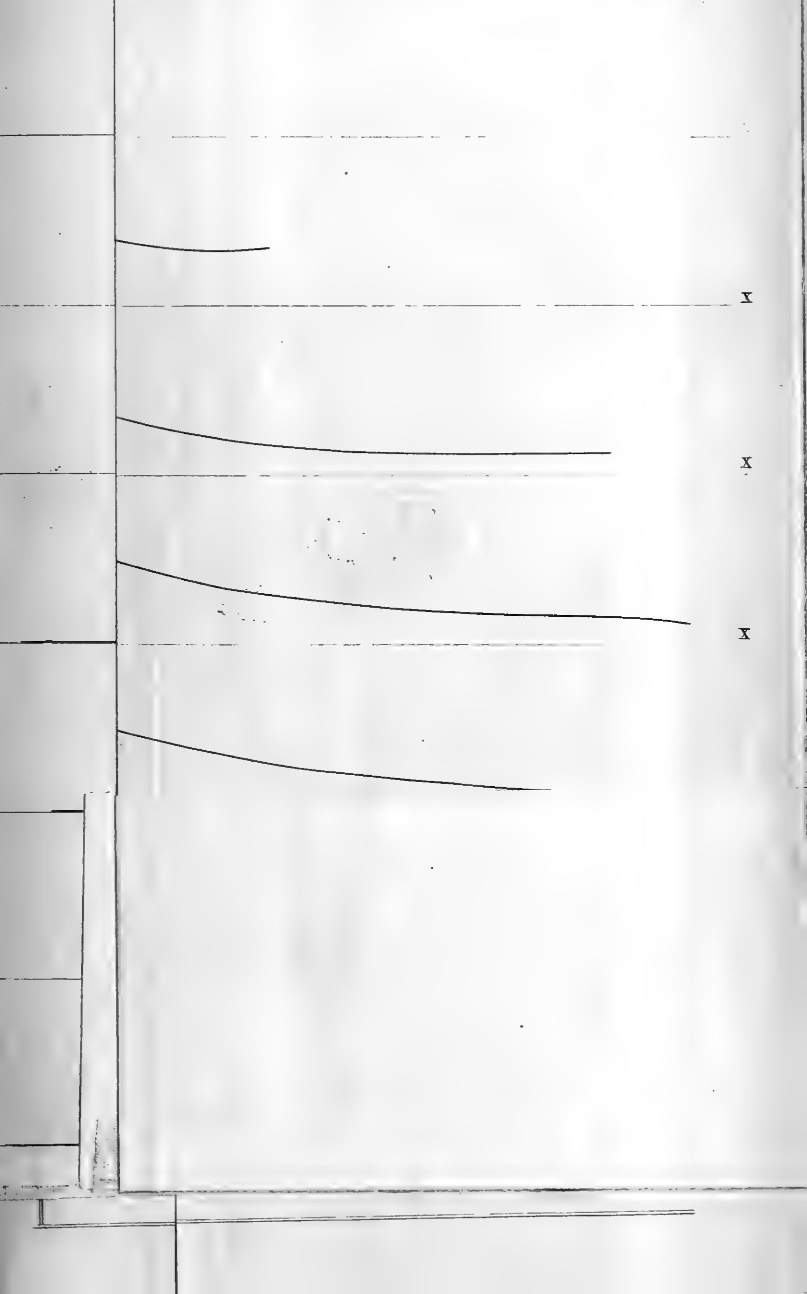


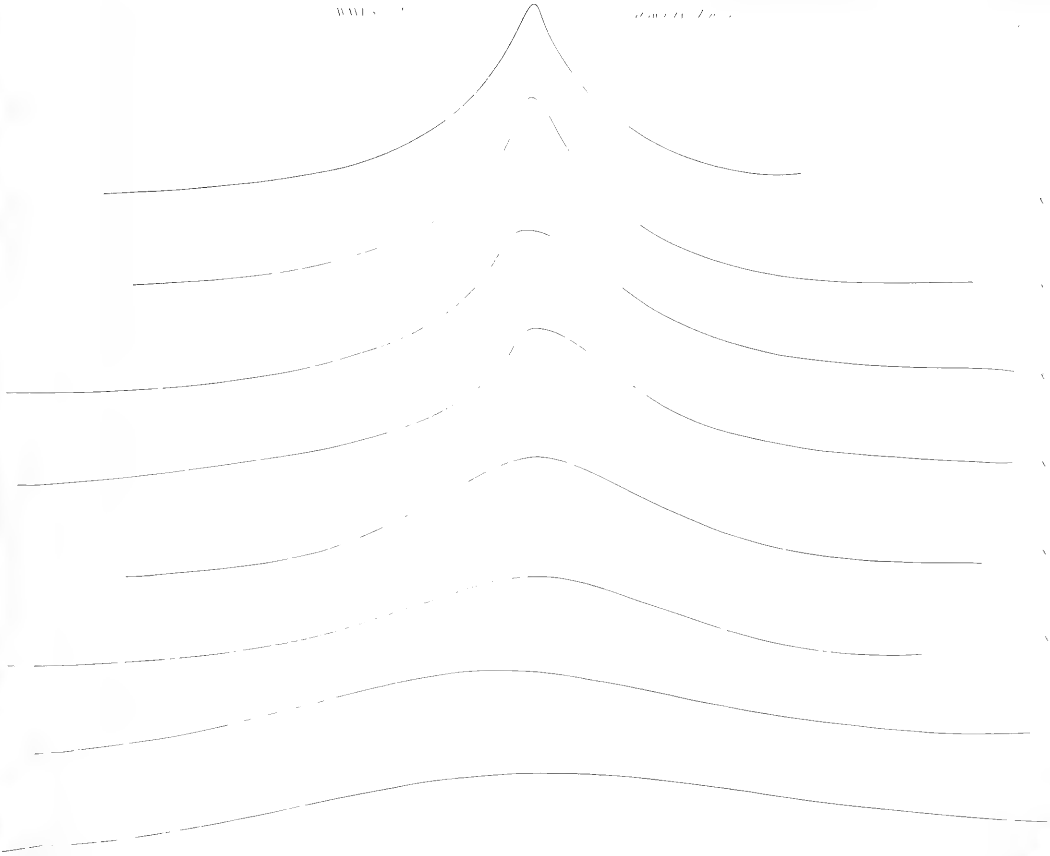
Waves of the Sea Shore *Fig. 7*

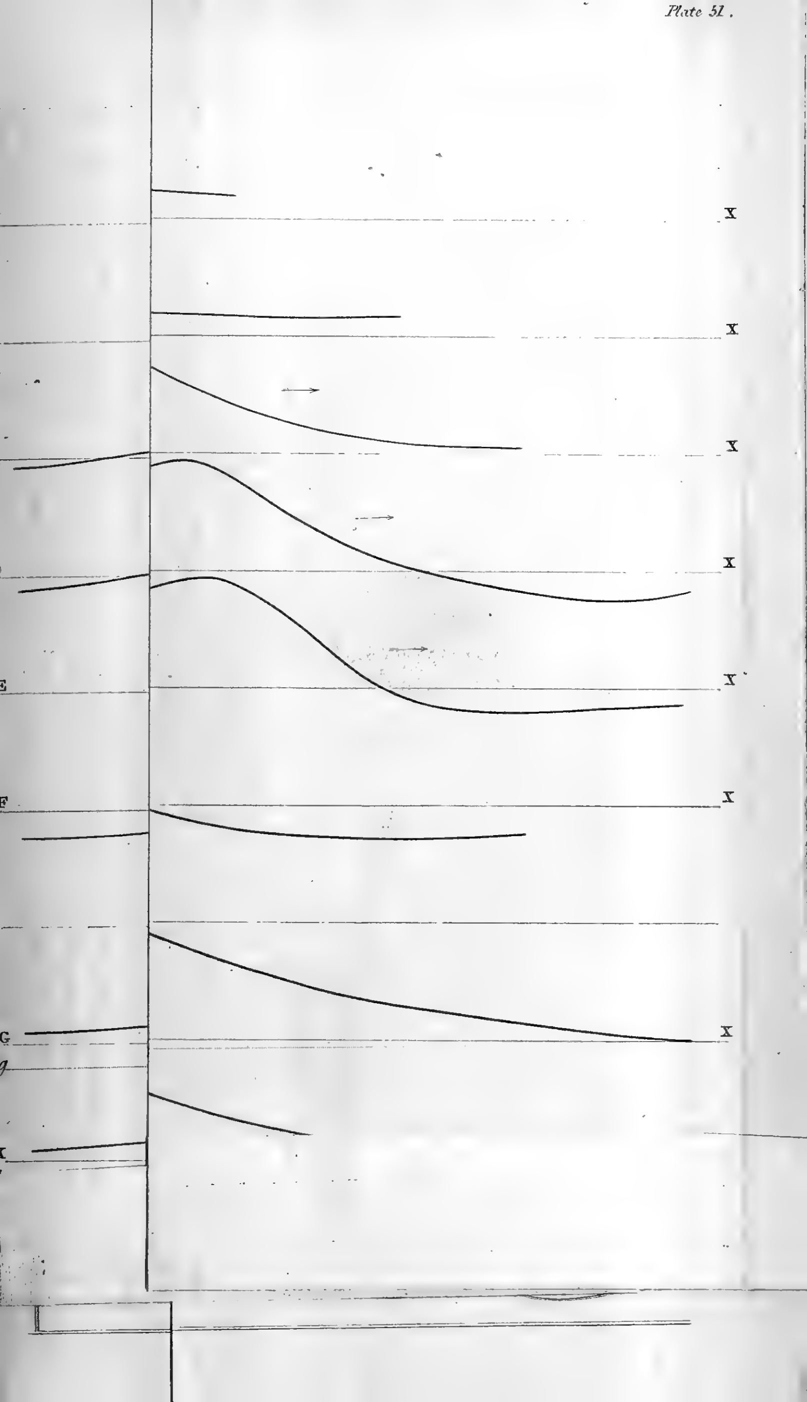


selves.

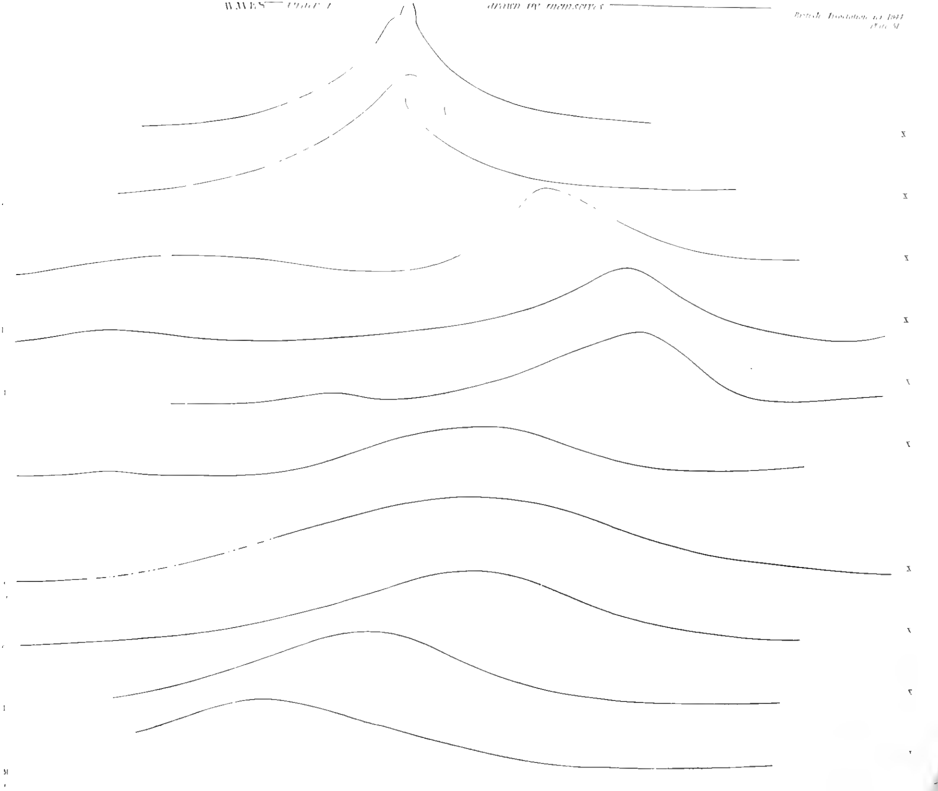
British Aſsociation for 1844.
Plate 50.





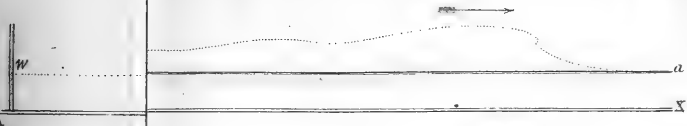

X
X
X
X
X
E
F
X
G
g
X

WAVES — Plate I   drawn by themselves

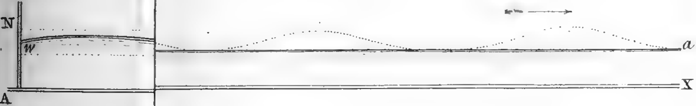


British Aſsociation for 1844.
Plate 52.

1.



2.



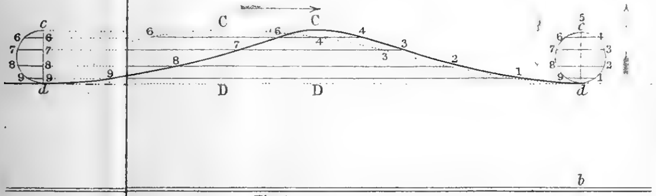


Fig. 4.

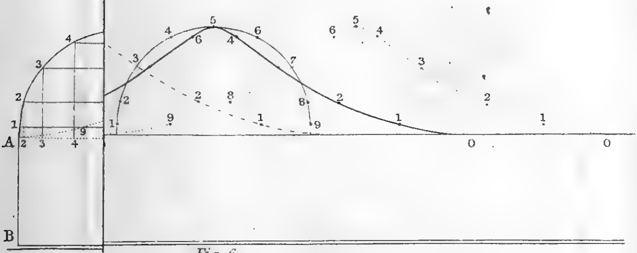
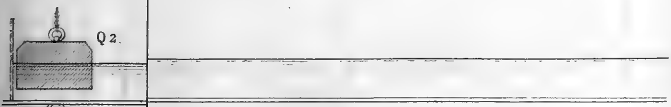
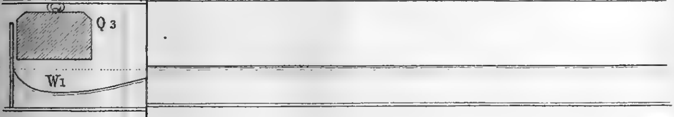
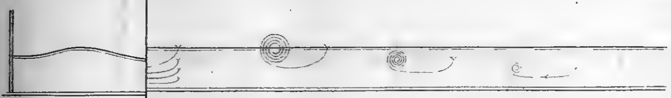


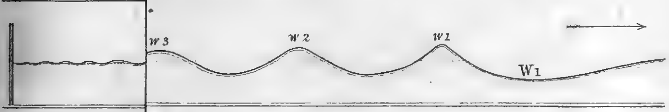
Fig. 6.

7.





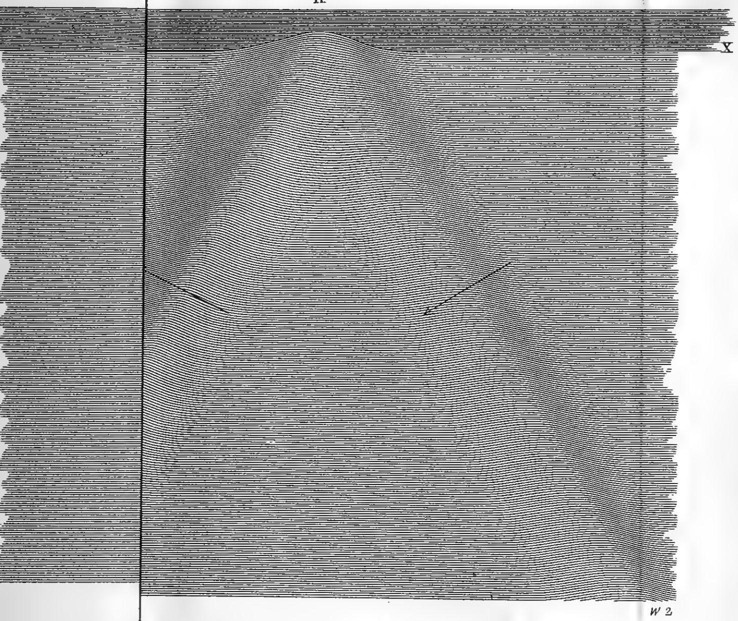


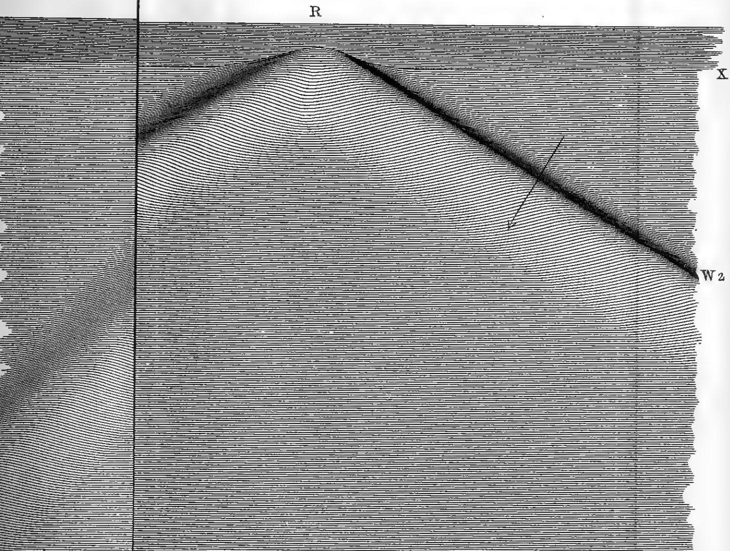


British Association 1844
Plate 52

WAVES *Order I*

WAVES [illegible]


X
W 2


R
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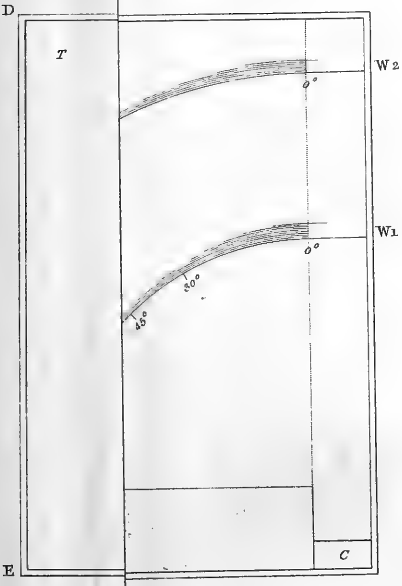
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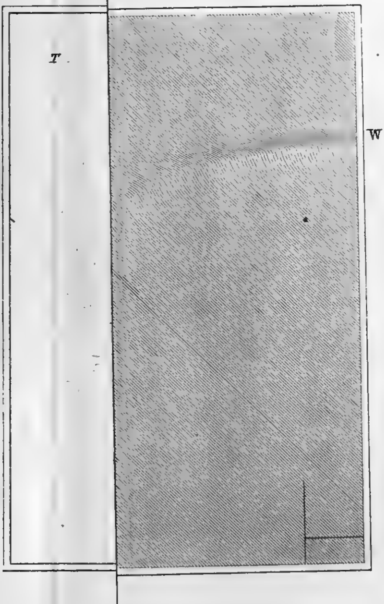
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Fig. 1

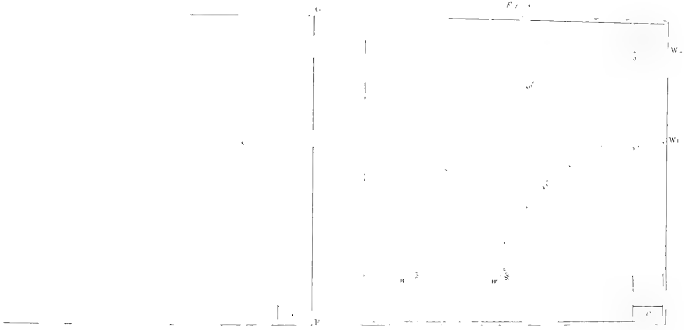
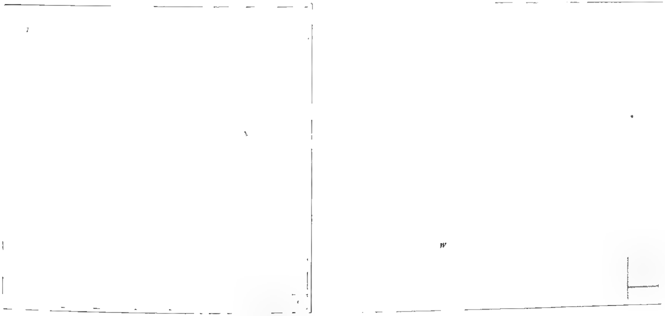
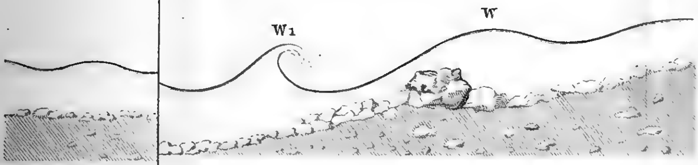


Fig. 2

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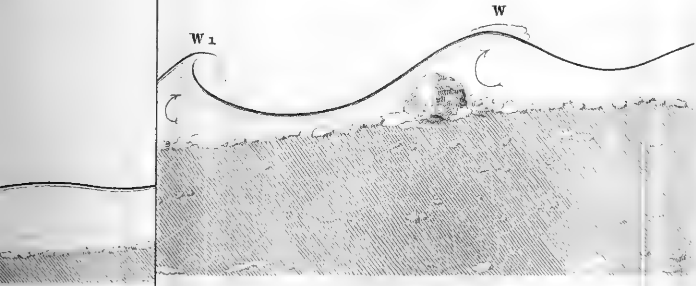
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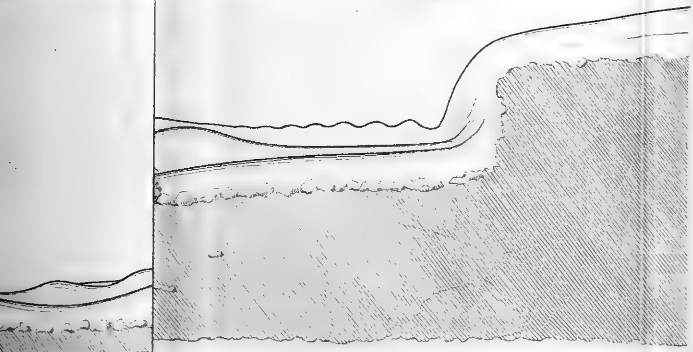


Fig 1

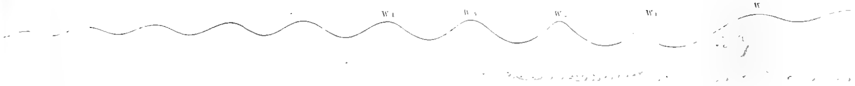


Fig 2

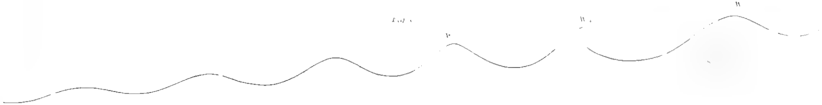
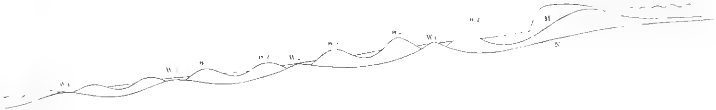


Fig 3



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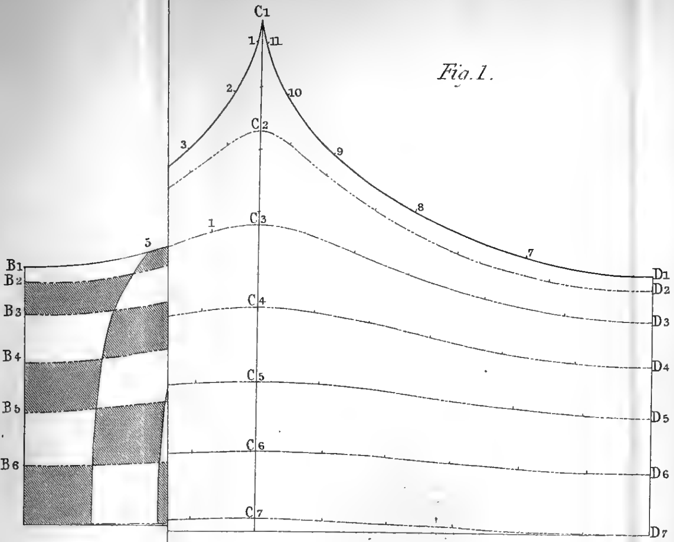

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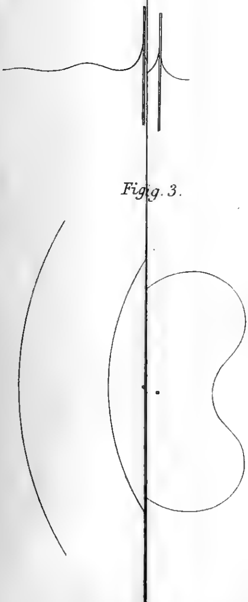


Fig. 3.

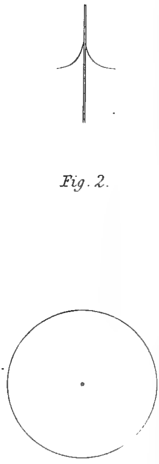
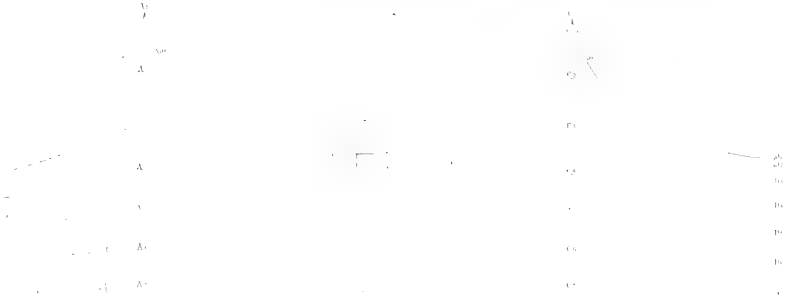


Fig. 2.

WAVES *Cycle II*



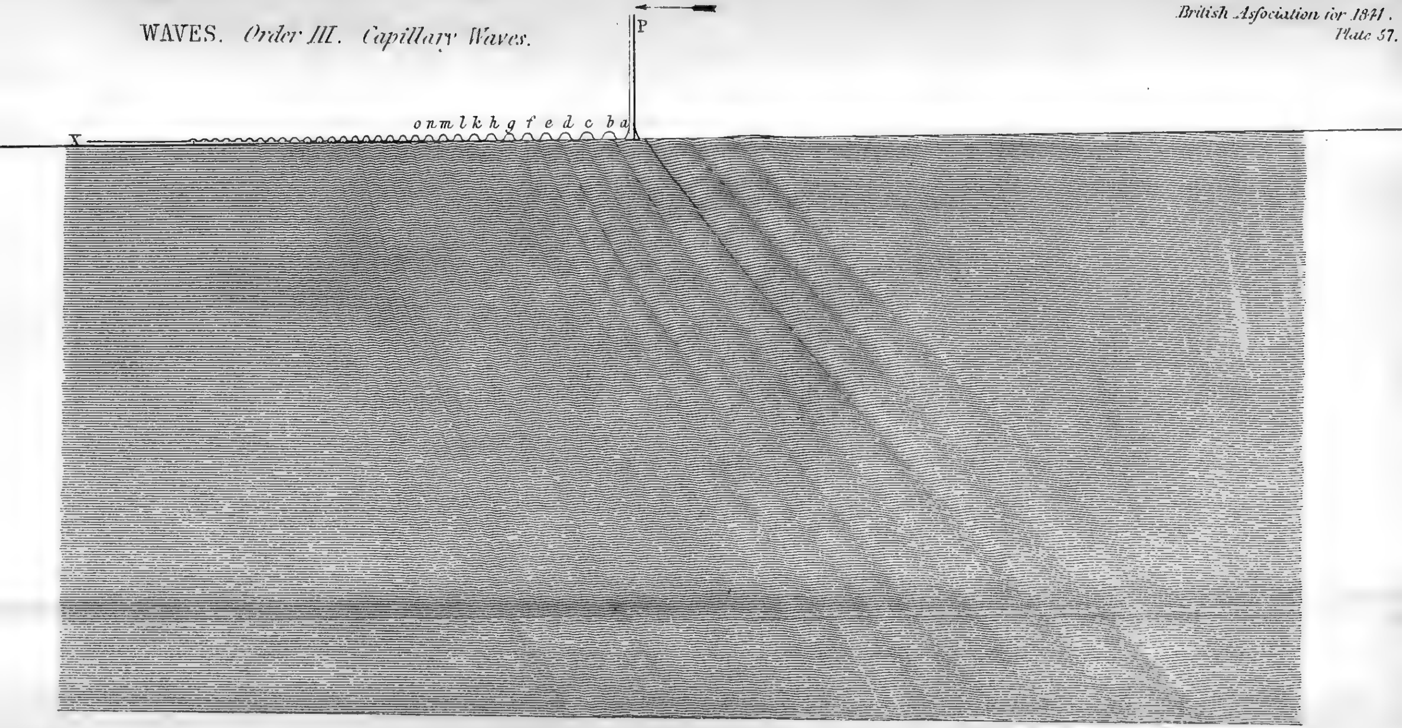
WAVES *Cycle III*

Fig. 6

Fig. 7

British Asſociation for 1841.
Plate 57.

WAVES. *Order III. Capillary Waves.*



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